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REVEGETATING STRIP-MINED LAND WITH MUNICIPAL SEWAGE SLUDGE

by

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Three sites representative of abandoned, barren bituminous and anthracite mines were treated with various types of municipal sludge at high and low application rates and broadcast seeded with a mixture of grasses and legumes. A monitoring system was installed at each demonstration site to determine the effects of the sludge applications on groundwater and soil percolate water chemical and bacteriological quality, chemical properties of the soil, and quality and growth of vegetative cover.

Data collected during the 3-year period indicate that the sludge applications ameliorated the harsh site conditions and resulted in a quick vegetative cover that completely stabilized the demonstration site. Moreover, each site's vegetative cover has persisted and improved each year since its establishment. No deterioration in vegetation yield or quality has been observed. Although sludge applications increased some trace metal concentrations in the vegetation, all concentrations were below plant tolerance levels and no phytotoxicity was observed. Sludge applications have no significant adverse effect on soil percolate or groundwater chemical or bacteriological quality.

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report demonstrates methods of using municipal wastewater sludge to ameliorate and revegetate the acidic spoils left from surface mining of coal.

Francis T. Mayo, Director
Municipal Environmental Research Laboratory

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ABSTRACT

The use of municipal sludge to revegetate mined land in an environmentally acceptable manner was demonstrated on several 4-hectare plots in the anthracite and bituminous coal mining regions of Pennsylvania.

Three sites representative of abandoned, barren bituminous and anthracite mines were treated with various types of municipal sludge at high and low application rates and broadcast seeded with a mixture of grasses and legumes. A monitoring system was installed at each demonstration site to determine the effects of the sludge applications on groundwater and soil percolate water chemical and bacteriological quality, chemical properties of the soil, and quality and growth of vegetative cover.

Data collected during the 3-year period indicate that the sludge applications ameliorated the harsh site conditions and resulted in a quick vegetative cover that completely stabilized the demonstration site. Moreover, each site's vegetative cover has persisted and improved each year since its establishment. No deterioration in vegetation yield or quality has been observed. Although sludge applications increased some trace metal concentrations in the vegetation, all concentrations were below plant tolerance levels and no phytotoxicity was observed. Sludge applications has no significant adverse effect on soil percolate or groundwater chemical or bacteriological quality.

The results from these demonstration projects indicate that stabilized municipal sludges, if applied properly, can be used to revegetate mined lands in an environmentally safe manner with no adverse effects on the vegetation, soil, or groundwater quality.

This report was submitted in fulfillment of Grant No. S-804511-020 by the Pennsylvania Department of Environmental Resources under the sponsorship of the U. S. Environmental Protection Agency. The report covers the period November 1976 to October 1979, and work was completed as of December 1979.

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We would also like to recognize the land owners who made sites available for the demonstration projects. The Pengrove Coal Company provided the site in Venango County; the Pennsylvania Department of Transportation provided the site in Lackawanna County; and Victor Smith provided the site in Westmoreland County.

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SECTION 1

INTRODUCTION

Much of our Nations need for energy is currently being supplied and will probably continue to be supplied from our coal reserves. With the increasing price of oil, the demand for coal is expected to more than double by 1985. Though the production of anthracite coal from deep mining has been decreasing, the production of bituminous coal by strip mining has been steadily increasing. Estimates show that strip mining will account for 67 percent of the anticipated increased production (Hill and Montague, 1976).

The strip-mining industry has already disturbed approximately 1.6 million ha of land in the United States, of which, slightly less than 607,500 ha has been properly reclaimed. Strip mining of bituminous coal has affected 31 states. The U.S. Geological Survey has estimated that approximately 2,590 km^2 of land is disturbed annually by strip mining (Strip and Surface Mine Study Policy Committee, 1967). In Appalachia alone, more than 400,000 ha of land has been disturbed by strip mining, with more than 25% of it in Pennsylvania. Only half of this land has been adequately revegetated. In Pennsylvania, strip and surface mining of coal has adversely affected an estimated 4,800 km of streams and 810 ha of impoundments as a result of erosion and acid mine drainage. In addition, it has caused the loss of productive cropland and forestland, wildlife habitat, and recreational and hunting areas. Though current mining laws require proper back-filling and restoration of the land, much of the mining was done before such laws existed. Many of the old strip mine sites are a constant source of silt in streams from soil erosion. The rain that falls on these sites erodes the mine spoil and carries it to natural water courses, where it causes pollution of surface streams or rapidly percolates through the porous spoil material and adds to the acid drainage problems of the mining areas. The lack of a vegetative cover on old sites thus contributes both to pollution from soil erosion and acid drainage.

Strip mine spoils are notoriously difficult to revegetate. Most provide a harsh environment for seed germination and subsequent plant growth. Major problems are usually a lack of nutrients and organic matter, low pH, low water-holding capacity, toxic levels of trace metals, and poor physical characteristics. To alleviate these conditions, large applications of lime and fertilizer are often required. In some instances, organic soil amendments and mulches are necessary to obtain satisfactory vegetation establishment.

Cities and towns throughout Appalachia have benefited from Federal and State sewage treatment plant construction grants. The construction of treatment plants has done much to reduce health hazards, abate water pollution, and upgrade water quality. The cost of operating such plants places a burden

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on municipalities, and one of the most costly items in treatment plant budgets is sludge disposal. Higher degrees of sewage treatment result in larger quantities of sludge that must be handled in an environmentally satisfactory manner.

Sewage sludge incinerators were used to dispose of sludge for many years. The ash produced was landfilled and presented no particularly difficult disposal problems. Incinerators are now being phased out of service throughout Pennsylvania as air quality standards become more restrictive. The high cost of fuel to fire conventionally designed incinerators and its limited availability have contributed to the rapid decline in sludge incineration in Pennsylvania. This changing situation presents a problem and an opportunity. More sludge that could be applied constructively to land renovation will now be available.

During the past decade, a considerable amount of research has been conducted that has shown that stabilized municipal sludge from secondary wastewater treatment plants is an excellent soil amendment and chemical fertilizer substitute. It is estimated that more than 4.5 million dry metric tons (mt) of municipal sludge is currently being produced annually in the United States. By the time secondary treatment is achieved by all wastewater treatment facilities across the country, this volume of sludge may reach 8 million dry mt per year (League of Women Voters, 1976). Current methods for sewage sludge disposal are land filling (40%), incineration (25%), ocean dumping (15%), and land application (20%). Of these, only land application provides an opportunity for disposal and beneficial use at the same time.

Farmers have used animal wastes as soil conditioners for centuries. Sewage sludges have been used for this purpose in many parts of the world. The availability of inexpensive chemical fertilizers in the United States probably has resulted in limited instances of sewage sludge being used as a soil builder and conditioner. Recent increases in the cost of chemical fertilizer should make the nutrient content of sewage sludge more attractive to farmers.

Though the benefits of utilization of sewage sludge seem obvious, there is some reluctance on the part of farmers and local government officials to undertake such projects. Demonstration projects are needed to illustrate the benefits of land disposal. Strip mine sites that have been removed from agricultural productivity and contribute to soil erosion and siltation problems seem to be logical areas for such a demonstration.

PURPOSE

The purpose of this project was three-fold: 1) to reclaim land that has been damaged by strip mining so that it can be returned to useful agricultural purposes; 2) to reduce erosion and stream siltation; and 3) to demonstrate that municipal sludge can be used in an environmentally acceptable manner to revegetate lands disturbed by mining activities.

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In addition, the project was also designed to demonstrate the use of sewage sludge as (1) a source of nutrients for agricultural production, strip-mined land reclamation and stabilization, and the control of siltation, sedimentation, and erosion; (2) a substitute for fertilizer in certain instances to conserve petroleum products; (3) an energy conservation method through the curtailment of sludge incineration and the use of auxiliary fuels; and (4) an economic and environmental benefit to communities that are burdened with the disposal of sewage sludge.

OBJECTIVES

The specific objectives of the projects were as follows:

1. To demonstrate the feasibility of using municipal sewage sludge to reclaim and vegetate land disturbed by mining activities.
2. To evaluate methods for the processing, transportation, spreading, and incorporation of the sludge into the land.
3. To demonstrate application rates that will maximize benefits to soils, improve water quality, and make lands agriculturally productive.
4. To evaluate the effect of varied sludge applications on vegetation establishment and growth, including foliar analysis to determine nutrient uptake and potential heavy metal toxicity.
5. To evaluate the effect of the sludge applications on the chemical and bacteriological quality of soil percolate water and groundwater.
6. To determine the degree of amelioration of harsh site conditions by monitoring physical and chemical changes of the surface spoil or refuse material from sludge application.
7. To evaluate the chemical characteristics of municipal sludge before application.
8. To determine the economic feasibility of application to strip-mined land in relation to alternative methods of sludge disposal.

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SECTION 2

CONCLUSIONS

The results from these demonstration projects indicate that stabilized municipal sludges can be used to revegetate bituminous strip-mined land and anthracite refuse banks in an environmentally safe manner with no adverse effects on vegetation, soil, or groundwater quality and with little risk to animal or human health. Specific conclusions based on results obtained at each demonstration site are as follows:

VENANGO COUNTY DEMONSTRATION

1. Application of dewatered sludge at rates of 90 and 184 mt/ha produced a complete vegetative cover of grasses and legumes within 2 months on a bituminous strip-mine spoil bank.

2. Application of liquid digested sludge at rates of 103 and 155 m^3/ha (equivalent to 7 and 11 mt/ha) produced a similar complete vegetative cover.

3. Vegetative height growth ranged from 29 to 35 cm during the first growing season. Vegetation height growth continued to increase throughout the three growing seasons (1977-79) following sludge application.

4. Vegetative dry matter production ranged from 4757 to 6349 kg/ha during the first growing season. Dry matter productivity continued to increase throughout the three growing seasons (1977-79) following sludge application. Adjacent untreated areas were essentially devoid of vegetation.

5. Foliar concentrations of nutrients, cations, and trace metals in vegetation were higher on sludge-treated areas. Most foliar trace metal concentrations decreased during the second and third year. All foliar trace metal concentrations were below plant tolerance levels, and no phytotoxicity symptoms were observed.

6. Liming, in addition to the sludge applications, did not significantly reduce the availability of trace metals for plant uptake.

7. The vegetative cover has steadily improved over the three growing seasons following sludge application. No decrease in yield nor deterioration in quality of vegetation has been observed.

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8. The highest application of dewatered sludge (184 mt/ha) slightly increased the concentration of NO_3-N in soil percolate water at the 90-cm depth during the first 3 months following application in 1977. Highest monthly average concentration was 13.0 mg/l. After vegetation establishment, concentrations of NO_3-N decreased below the allowable maximum for potable water (10 mg/l) and remained there throughout 1978 and 1979. Concentrations of NO_3-N in soil percolate water on adjacent untreated areas ranged from 0.5 to 2.8 mg/l.

9. The highest application of liquid digested sludge (11 mt/ha) significantly increased the concentration of NO_3-N in soil percolate water at the 90-cm depth during the first 2 months following application. Highest monthly average concentration was 33.9 mg/l. This was partially due to the fact that the NO_3-N concentration was much higher (1780 ppm) in the liquid digested sludge than in the dewatered sludge (46 ppm) and was more susceptible to leaching before vegetation establishment. After vegetation establishment, NO_3-N concentrations decreased to levels below 10 mg/l and remained at low levels throughout 1978 and 1979.

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10. Sludge applications did not significantly increase trace metal concentrations in soil percolate water. Only slight increases in concentrations of Zn, Ni, and Co were observed during the first year in the percolate collected from the 184-mt/ha sludge-treated area. Percolate water quality met U.S. Public Health Service (USPHS) drinking water standards with only a few exceptions. Concentrations of Zn and Ni exceeded the standards during the first 3 months (1977) on the 184-mt/ha sludge-treated area. Concentrations of Cr and Pb exceeded the standards on both control and sludge-treated areas. During the second and third years, only concentrations of Pb exceeded potable water standards on both the control and the area receiving the highest sludge application rate.

11. No fecal coliforms were found in any soil percolate water samples collected after sludge application during the period May 1977 through October 1979.

12. Sludge applications did not significantly affect the groundwater concentrations of orthophosphate-P, NO_3-N, NH_4-N and organic-N or pH. Average monthly concentrations of NO_3-N were consistently below 10 mg/l during the 3-year period. The only significant effect was a short-lived peak in NO_3-N concentration (to 16.0 mg/l) in the groundwater well influenced by the liquid digested sludge application. This peak occurred during the first month following sludge application and was correlated with the high NO_3-N concentrations found in the soil percolate water samples.

13. Sludge applications did not significantly increase trace metal concentrations in groundwater. Most trace metal concentrations met USPHS drinking water standards over the 3-year period. Lead was the only element which exceeded drinking water standards on both control and sludge-treated areas.

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14. No fecal coliforms were found in any groundwater samples collected after sludge application during the period July 1977 through October 1979.

15. The highest sludge application (184 mt/ha) significantly increased the amount of Bray phosphorus in the 0- to 15-cm soil depth. Concentrations remained at high levels throughout the following 18 months.

16. The highest sludge application reduced the amount of total sulfur in the soil at all depths (0 to 15, 15 to 30, and 30- to 60-cm).

17. The highest sludge application did not significantly increase the amount of Kjeldahl nitrogen in the soil during the first 4 months. However, significant increases were noted during the second year, particularly at the 0- to 15-cm depth. Nitrogen concentrations in the 0- to 15-cm depth were almost doubled 18 months after sludge application.

18. The highest sludge application resulted in some slight increases in trace metal concentrations in the soil 4 months after sludge application. However, these concentrations were extremely low and were below the normal range for Pennsylvania soils. All trace metal concentrations decreased during the 18 months after sludge application.

19. Sludge application and liming significantly increased soil pH. Treatments increased pH of the 0- to 15-cm soil depth from 3.8 to an average of 6.8 within 4 months. These increased pH levels were maintained throughout the following 3 years, reaching an average of 7.4 in October 1979.

LACKAWANNA COUNTY DEMONSTRATION

1. Application of dewatered sludge at rates of 80- and 108-mt/ha produced a complete vegetative cover of grasses and legumes within 2 months on an anthracite refuse bank.

2. Average vegetation height growth during the first year (1978) was 35 and 47 cm for the 80- and 108-mt/ha sludge application rates. Average height growth was almost doubled during the second growing season (1979), averaging 81.5 cm.

3. Average vegetative dry matter production the first growing season was 3988 and 3321 kg/ha for the 80- and 108-mt/ha sludge application rates. Dry matter productivity more than doubled during the second growing season, averaging 7723 kg/ha.

4. Foliar concentrations of nutrients, cations, and trace metals in vegetation were increased by the sludge applications. There was little difference between concentrations for the two sludge appli-

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cation rates. In general, foliar concentrations of trace metals decreased during the second growing season. Trace metal concentrations of Zn, Cr, Pb, and Ni were higher in grasses on control areas than on the sludge-treated areas. All trace metal concentrations were below plant tolerance levels, and no phytotoxicity symptoms were observed.

5. Concentrations of NO_3-N in soil percolate water at the 90-cm depth were not significantly increased by the sludge applications. The highest average monthly concentration recorded during the 2 years following sludge application was 1.5 mg/l.

6. Applications of lime and sludge has no significant effect on soil percolate water pH, which remained at levels below 5.0 before and after treatment.

7. Sludge applications did not significantly increase trace metal concentrations in soil percolate water. Trace metal concentrations decreased during the second year. Concentrations of all trace metals in soil percolate water were below the maximum allowable limits for potable water.

8. No fecal coliforms were found in any soil percolate water samples collected after sludge application during the period July 1978 to October 1979.

9. Sludge applications did not significantly affect the groundwater concentrations of orthophosphate-P, NO_3-N, NH_4-N and organic-N or pH. Average monthly concentrations of NO_3-N were consistently below 0.5 mg/l during the 2 years after sludge application.

10. No fecal coliforms were found in any groundwater samples collected after sludge application during the period July 1978 to October 1979.

WESTMORELAND COUNTY DEMONSTRATION

1. Application of composted sludge at the rate of 134-mt/ha during the fall season (September 1979) produced an adequate vegetative cover of winter rye to protect the site from erosion and runoff during the winter season.

2. Sludge application did not significantly affect the soil percolate water concentrations of orthophosphate-P, NO_3-N, NH_4-N, and organic-N or pH. Nitrate-N concentrations were extremely low (<2.0 mg/l) before sludge application and remained at these low levels during the first 4 months following sludge application.

3. Sludge application did not significantly affect trace metal concentrations of soil percolate water during the 4 months following

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application. Concentrations of all elements except Pb met USPHS drinking water standards. Lead concentrations exceeded these limits on both the control and sludge-treated areas.

4. Sludge application did not have any significant effect on groundwater quality during the 4 months following application. Nitrate-N concentration remained below 10 mg/l. Concentrations of all trace metals except Pb were below the maximum allowable limit for potable water. Lead concentrations exceeded this limit on both the control and sludge-treated area.

5. No fecal coliforms were found in any soil percolate or groundwater samples collected during the 4 months after sludge application.

GENERAL

1. Results indicate that the use of these small, local demonstration projects is one of the best methods of obtaining public acceptance and support for the revegetation of strip-mined land using municipal sewage sludge. All projects were highly successful. Project results should be useful throughout the Appalachian coal mining region. Many factors such as recent environmental legislation, escalating land costs, increasing energy costs, and greater concerns about safeguarding the oceans, air quality, and water supplies are forcing many municipalities to reconsider their current methods of sludge processing and disposal. Large coastal metropolitan areas currently disposing of sludge in the oceans are particularly hard pressed to find an alternate environmentally acceptable method as ocean dumping is being phased out. Most current methods of sludge disposal - ocean dumping, landfilling, and incineration - are costly, wasteful, and unproductive. Results from this project show that sludge is a valuable resource and should be utilized. Its utilization for revegetation of strip-mined land provides an opportunity for environmentally safe disposal and beneficial use at the same time. Both sludge production and strip mining for coal are increasing and there is an urgent need to solve the environmental problems associated with both activities. Results from this project should be useful to state regulatory agencies in the development of guidelines or regulations related to the use of municipal sludge for the revegetation of strip-mined land.

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SECTION 3

RECOMMENDATIONS

1. Continued study is needed to evaluate the longevity of the sludge treatments and to determine the optimum application rates to achieve permanent revegetation.

2. Continued study is needed to evaluate the effectiveness of the liquid digested sludge applications in comparison to the dewatered and composted sludge applications.

3. Continued study is needed to evaluate the permanence of the vegetation cover established with single sludge applications, particularly, in relation to the proposed regulations under the Surface Mining Control and Reclamation Act of 1977 requiring that the vegetative cover be maintained for a minimum of 5 years.

4. Continued study is needed to evaluate the permanence of the sludge treatments on the amelioration of the surface spoil material.

5. Additional studies should be conducted to compare sludge treatments with conventional methods now being used for the revegetation of strip mined land. In view of the new strict revegetation requirements now being developed by the Office of Surface Mining Reclamation and Enforcement, current conventional methods will have to be modified. More seed, lime, and fertilizer will have to be used escalating the cost of reclamation. In addition, annual applications of chemical fertilizer may be necessary. Thus single applications of municipal sludge might become more cost effective.

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SECTION 4

VENANGO COUNTY DEMONSTRATION

SITE SELECTION

Original project design specified the selection of two demonstration sites, one in the anthracite coal region (Northeastern Pennsylvania) and the other in the bituminous coal region (Western Pennsylvania). The location of these coal fields is shown in Figure 1. A team of representatives from the cooperating agencies selected the first site in the bituminous coal mining region (Figure 1). This site owned by the Pengrove Coal Company is located in Irwin Township, Venango County (Figure 2). The site was selected because it was representative of bituminous strip mine spoil banks which had been recontoured without topsoil replacement. Several previous attempts to revegetate the area with lime, commercial fertilizer, and seed were unsuccessful and the demonstration site was essentially barren. Four hectares of the approximately 40 hectares of disturbed land were selected for sludge application.

DEMONSTRATION PROJECT DESIGN

To maximize the value of the demonstration project, both liquid digested sludge and stabilized dewatered sludge were used. Four 1.0 hectare plots were established for the application of digested liquid and dewatered sludge; each sludge type was applied at a high and low application rate. In addition, lime was applied to one-half of the sludge-treated plots.

Pre-Treatment Soil Sampling

Twenty-one soil pits were excavated on the demonstration site with a backhoe to a depth of 90 cm. Each pit was used for the collection of soil samples and for the installation of suction lysimeters for leachate water sample collection. Three soil pits were excavated in each sludge treatment sub-plot and in an adjacent control. Soil samples were collected at the 0-15, 15-30, 30-60, and 60-90 cm depth for chemical analyses. These samples were analyzed for Kjeldahl nitrogen, Bray phosphorus, pH, Ca, Mg, Na, K, Cu, Zn, Co, Ni, Cr, Pb, Cd, Fe, Mn, Al, and total sulfur. Samples were prepared for analysis by air drying and sieving to pass a 2 mm screen. Chemical procedures are given in the Appendix.

Monitoring Instrumentation

A monitoring system was established to determine the effects of the

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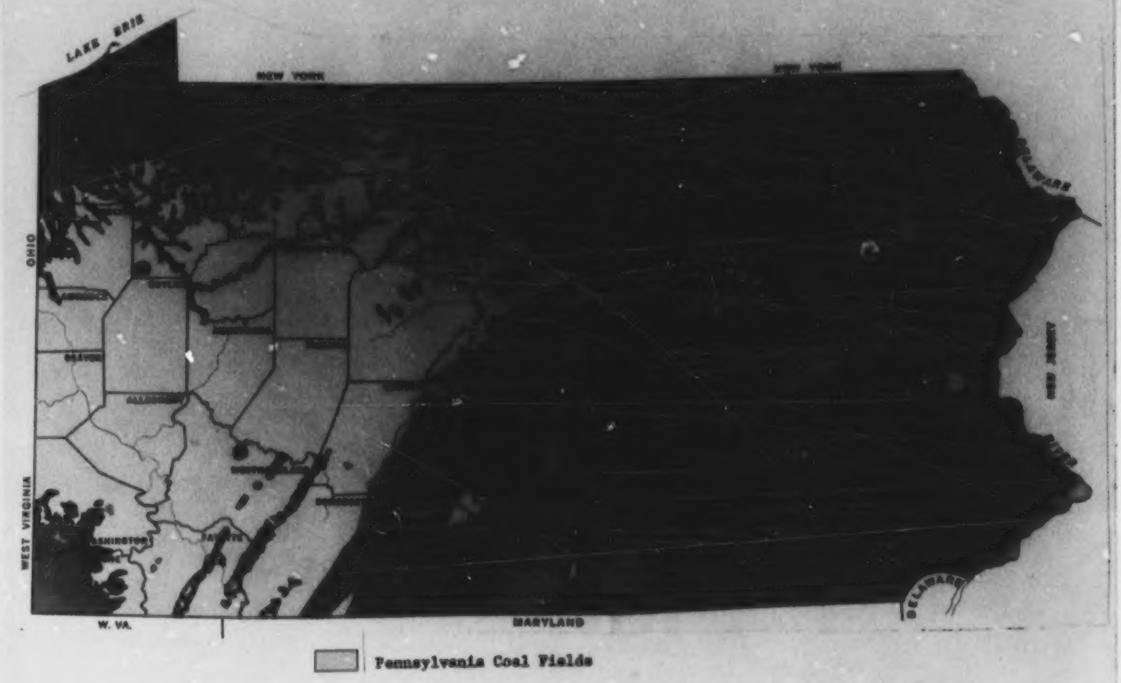
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NEW YORK
NEW YORK
DELAWARE
OHIO
WEST VIRGINIA
W. VA.
MARYLAND
DELAWARE
▨ Pennsylvania Coal Fields

Figure 1. General location of demonstration sites in the coal mining areas in Pennsylvania.

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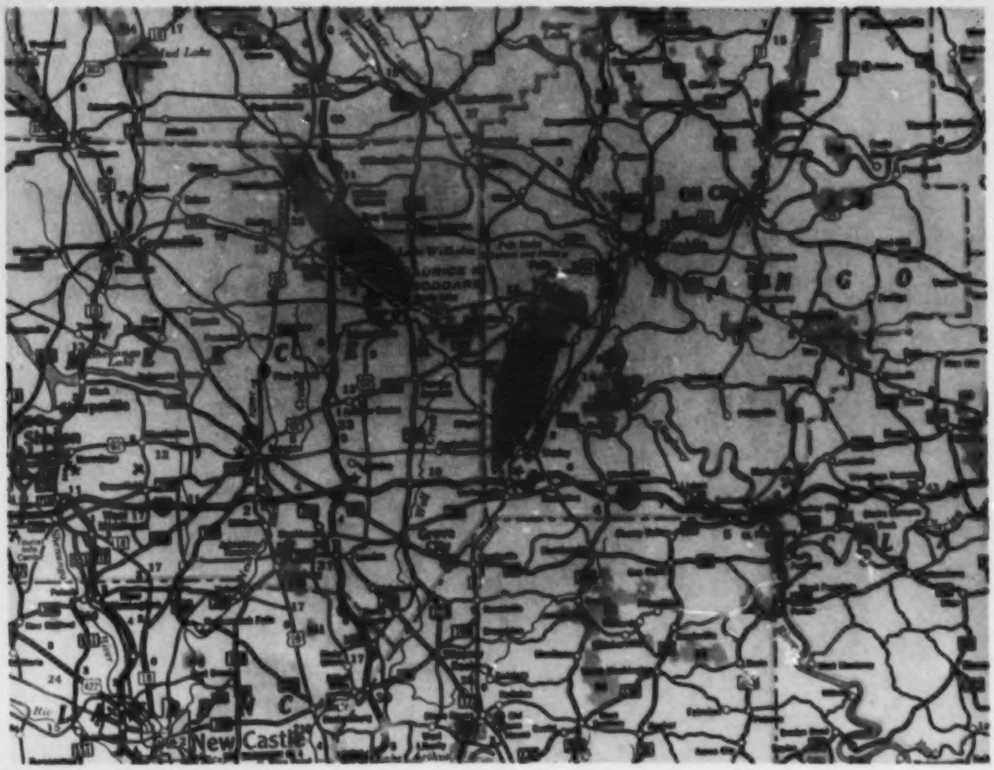

Figure 2. Specific location of the demonstration site on the Pengrove Coal Company land at Barkeyville, Pennsylvania.

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sludge applications on groundwater and soil percolate chemical and bacteriological quality, on the chemical properties of the soil, and on the vegetation.

Two suction lysimeters were installed at the 90 cm soil depth for the collection of percolate water samples. One was used specifically for the collection of percolate water for bacterial analyses (total and fecal coliform) and the other for routine chemical water quality analyses. Samples were collected bi-weekly for the first five months and then monthly thereafter. Samples were analyzed for pH, orthophosphorus-P, NO_3-N, NH_4-N, Organic-N, Ca, Mg, Na, K, Cu, Zn, Co, Cr, Ni, Pb, Cd, Fe, Mn, and Al. Chemical procedures are given in the Appendix.

Three 15-cm diameter groundwater wells were drilled to monitor the effects of the sludge applications on groundwater quality. Groundwater well sites were selected by geologists of the Pennsylvania Department of Environmental Resources. The depth of each well and the depth to the water level at the time of drilling was as follows:

Well No.	Total Depth m	Depth to Water Level m
1	18.0	5.3
2	17.8	3.3
3	11.4	2.1

Groundwater well samples were collected on the same schedule as percolate water samples. Samples were collected with both a submersible pump and a Kemmerer water sampler. The pump was used to remove standing water and draw-down the well. After recovery, the pump was used to obtain a sample of fresh water in the well. A small subsample was acidified with nitric acid at the time of collection for heavy metal analyses. Samples were analyzed for the same constituents as the soil water percolate samples.

Water samples were also collected from two lakes adjacent to the demonstration plots. The samples were analyzed for the same constituents as the soil percolate water samples.

SLUDGE ANALYSIS

Sludge for the demonstration project was obtained from local wastewater treatment plants at Farrell, Franklin, and Oil City, Pennsylvania. Liquid sludge was obtained from Farrell and Oil City and dewatered sludge from Franklin and Oil City.

The City of Farrell Water Pollution Control Plant currently treats 4,900 cubic meters of wastewater per day serving a population of 11,000. Treatment consists of primary settling, activated sludge, and final settling. Solids collected in the final settling tanks are tank trucked to farmland for distri-

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bution by a local contractor. The City of Franklin General Authority waste treatment plant currently serves a population of 13,000 with a design rate of handling 11,200 cubic meters of wastewater per day. At this plant treatment consists of primary settling followed by anaerobic digestion. The sludge is then thickened by the addition of polymers, dewatered by centrifuging and trucked to a sanitary landfill. The waste treatment plant of Oil City General Authority has a design rate of handling 15,000 cubic meters of wastewater per day to serve a population of 32,600; currently they average 9,300 cubic meters of wastewater per day. The treatment at the plant consists of primary settling followed by anaerobic digestion. At this point the solids can be either dewatered or pumped as liquid digested sludge to tank trucks for land distribution. The liquid digested sludge can be dewatered by either vacuum filtering or pumping to sand drying beds. The dewatered sludge is ultimately trucked to a sanitary landfill.

Because of the diversity of waste treatment processes and the variation in concentration of constituents in the sludges, it was decided to mix the sludges on the site prior to application. Samples of the sludge mixture were collected as the sludge was applied on the demonstration plots. Six composite samples were collected as the dewatered sludge was applied and five composite samples were collected as the liquid sludge was applied. The results of these analyses are given in Table 1 (dewatered sludge) and Table 2 (liquid digested sludge). Average solids content for the liquid digested sludge was 3 percent and for the dewatered sludge was 52 percent. Average total nitrogen content was 1.3 percent for the dewatered sludge and 2.7 percent for the liquid digested sludge.

Results of the sludge analyses were used to calculate the amounts of selected nutrients and trace elements applied in the various application rates. These amounts, expressed in kilograms per hectare, are given in Table 3.

The recommended life-time loading rate for trace elements in sludges to be used for reclamation purposes according to the Pennsylvania Department of Environmental Resources (PDER) Interim Guidelines for Sewage Sludge Use for Land Reclamation (1977) are given in Table 4.

The U.S. Environmental Protection Agency (1977) recommendations for limits on the amounts of trace metals applied to agricultural soil via sewage sludge vary with the cation exchange capacity of the soils. These recommendations are given in Table 5.

A comparison of the maximum sludge application rate (184 MT/ha) with the EPA and PDER recommendations is given in Table 6. The amounts of trace metals applied in the sludge were below the PDER recommendations with the exception of copper. The amount of copper applied slightly exceeded the PDER recommendation but was well below the EPA recommendation.

The commercial fertilizer equivalents of the various sludge application rates are given in Table 7. The highest sludge application rate would be equivalent to applying 10 metric tons per hectare of an 11-9-0 commercial

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TABLE 1. CHEMICAL ANALYSIS OF DEWATERED SLUDGE APPLIED ON THE VENANGO COUNTY DEMONSTRATION PLOTS

Constituent	Mean	Range High	Range Low
pH	7.9	8.2	7.7
	---------- ppm on dry weight basis ----------		
Total P	4624	6327	2701
NO_3-N	46	52	40
NH_4-N	727	839	635
Org-N	12188	14612	9990
Total N	12962	15500	10768
Ca	9970	12699	3805
Mg	2082	3108	590
Na	286	350	235
K	93	142	44
Al	6133	8641	1208
Mn	1651	2703	285
Fe	29709	44561	5912
Co	22	34	13
Zn	811	1008	295
Cu	661	967	471
Pb	349	377	302
Cr	413	665	180
Ni	69	111	55
Cd	3.2	4.1	1.2
Hg	0.6	0.9	0.4
PCB	1.2	1.4	1.0

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TABLE 2. CHEMICAL ANALYSIS OF LIQUID DIGESTED SLUDGE APPLIED ON THE VENANGO COUNTY DEMONSTRATION PLOTS

Constituent	Mean	Range High	Low
pH	6.8	7.0	6.6
	-------- ppm on dry weight basis ---------		
Total P	5883	7293	4819
NO_3-N	1780	3869	528
NH_4-N	4217	6295	2633
Org-N	20509	25021	18010
Total N	26506	35185	21750
Ca	39726	63836	26344
Mg	6689	12051	4707
Na	6264	8734	3935
K	407	542	304
Al	19545	42083	6667
Mn	808	1022	531
Fe	28517	34460	20909
Co	21	25	19
Zn	1796	2138	1031
Cu	1750	2481	793
Pb	999	1201	741
Cr	1560	2521	409
Ni	113	129	95
Cd	8.8	14.1	5.7
Hg	0.9	1.6	0.4
PCB	1.5	2.7	0.1

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fertilizer. The value of the sludge as a commercial fertilizer substitute is quite obvious in this Table.

TABLE 3. AMOUNTS OF SELECTED NUTRIENTS AND TRACE ELEMENTS APPLIED BY EACH SLUDGE APPLICATION ON THE VENANGO COUNTY DEMONSTRATION PLOTS

	Sludge Application Rate in Metric Tons Per Hectare			
Constituent	184	90	11	7
	kg/ha			
Total N	2388	1165	284	187
P	918	448	63	41
K	18	9	4	2
Cu	129	63	21	13
Zn	147	72	21	13
Cr	74	36	16	10
Pb	55	27	10	7
Ni	12	7	1	0.7
Co	3	2	0.2	0.1
Cd	0.6	0.2	0.09	0.07
Hg	0.09	0.04	0.01	0.007

SITE PREPARATION

Scarification

Prior to sludge application a portion of the demonstration area was scarified with a tractor and chisel plow. This was necessary because the surface spoil material has been compacted in the leveling operation. In addition, the roughened surface would prevent any runoff of sludge should an unusually heavy rainfall occur during the sludge application operation. The 2.5 hectare area to receive the dewatered sludge was completely scarified. However, the chisel plow dug up many large rocks and brought them to the surface. As a result it was decided not to scarify the area to receive liquid digested sludge. However, as a precaution against sludge runoff, the perimeter of the plot was scarified.

Liming

Analyses of surface soil samples indicated that the average soil pH

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TABLE 4. LIFETIME MAXIMUM TRACE ELEMENT LOADING RATES FOR LAND RECLAMATION ACCORDING TO THE PENNSYLVANIA INTERIM GUIDELINES

Constituent	Maximum Loading Rate for Land Reclamation	Maximum Loading Rate Land Reclamation for Farming
	kg/ha	kg/ha
Cd	3	3
Cu	112	67
Cr	112	67
Pb	112	67
Hg	0.6	0.2
Ni	22	13
Zn	224	134

TABLE 5. EPA RECOMMENDED TOTAL TRACE METAL LOADINGS FOR AGRICULTURAL LAND

Metal	Soil Cation Exchange Capacity (meq/100g) 0-5	5-15	>15
	Amount of Metal (kg/ha)		
Pb	560	1120	2240
Zn	280	560	1120
Cu	140	280	560
Ni	140	280	560
Cd	6	11	22

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TABLE 6. COMPARISON OF TRACE METAL LOADINGS AT THE VENANGO COUNTY DEMONSTRATION PROJECT WITH EPA AND PDER RECOMMENDATIONS

Constituent	Sludge Application Rate 184mt/ha	- - Recommendations - - EPA (CEC 5-15)*	PDER
	- - - - - - - - - -	kg/ha - - - - - - - - - -	
Cu	129	280	112
Zn	147	560	224
Cd	0.6	11	3
Pb	55	1120	112
Ni	12	280	22
Cr	74	NR†	112
Hg	0.09	NR†	0.6

* Average CEC of site ranged from 11.6 to 15.2 meq/100g

† No recommendations given by EPA

TABLE 7. COMMERCIAL FERTILIZER EQUIVALENTS OF THE SLUDGE APPLICATION RATES IN VENANGO COUNTY

Sludge Application Rate	Fertilizer Equivalent (Fertilizer Formula)			
	Amount	N	P_2O_5	K_2O
mt/ha	kg/ha	kg/ha (%)	kg/ha (%)	kg/ha (%)
184	22,400	2388 (11)	2103 (9)	21 (0)
90	11,200	1165 (10)	1026 (9)	11 (0)
11	2,240	284 (13)	143 (6)	6 (0)
7	2,240	187 (8)	95 (4)	2 (0)

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was 3.9 (buffer pH 5.9) on the area to receive dewatered sludge. Therefore, agricultural lime was applied at the rate of 12.3 metric tons per hectare on one-half (1.0 hectares) of the area. This amount of lime should be sufficient to raise the soil pH to 7.0. Liming is necessary to immobilize the heavy metal constituents in the sludge and to prevent them from leaching into the groundwater.

Lime was applied to one-half of the area (1.0 hectares) to receive liquid digested sludge. Average soil pH was 6.1 (buffer pH was 6.6). Lime was applied at the rate of 4.5 metric tons per hectare.

SLUDGE APPLICATION

Liquid Digested Sludge

During the period May 17-23, 1977 liquid digested sludge was hauled in tank trucks (19,000-26,000 liter capacity) from the cities of Farrell and Oil City. At the site the liquid sludge was emptied from the tankers into a temporary small holding pond with a plastic liner. The pond provided a means for mixing the two sludges. A Badger Vacuum Tank Liquid Manure Spreader (Model BN-315) with a 5,700 liter capacity pumped the sludge from the holding pond and spread it on the plots. One-half of the demonstration area received liquid sludge at an application rate of 155 cubic meters per hectare (equivalent to 11 metric tons per hectare). The other half received sludge at the rate of 103 cubic meters per hectare (equivalent to 7 metric tons per hectare). It was not possible to apply the liquid digested sludge at the proposed design rate of 20 metric tons per hectare because of the extremely high solids content (approx. 17.2%) of the sludge from Oil City. After four areal applications with the Liquid Spreader, infiltration was restricted and no more sludge could be applied without the threat of producing surface runoff.

Dewatered Sludge

During the period May 18-21, 1977 dewatered sludge was transported by coal trucks from the cities of Franklin and Oil City. A total of 588 wet tons of sludge was transported to the site. The sludge from the two treatment plants was unloaded at the site and mixed with a front-end loader prior to application with a New Holland Manure Spreader (Model 328). One-half of the demonstration site (1.0 hectares) received an application of dewatered sludge at the rate of 90 metric tons per hectare and the other half (1.0 hectares) received 184 metric tons per hectare. Sludge spreading was completed by May 25, 1977. On May 26, 1977 a Steiger Bearcat II tractor with a 6.4-metric ton disc attachment (2 sets of 10 scalloped discs, 69 cm in diameter) was used to incorporate the sludge into the surface 10 cm of soil material.

VEGETATION SEEDING AND MULCHING

During the period May 27-31, 1977 the sludge-treated areas were broad-

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cast seeded with a mixture of two grasses and two legumes. The seed mixture used was:

	kgs per hectare
Kentucky 31 tall fescue	22
Pennlate orchardgrass	22
Penngift crownvetch	11
Birdsfoot trefoil	11
	66

The rationale for the selection of this seeding mixture is that the two grass species will germinate quickly and provide a complete protective cover the first year allowing time for the two legume species to become established and develop into the final vegetative cover.

The seed of the two grass species was mixed together and applied with a tractor-mounted Vicon Seeder (Model 500). The seed of the two legume species was innoculated, mixed together, and broadcast seeded with hand-carried whirlybird seeders. Immediately after seeding the entire 4 hectare demonstration site was mulched with straw and hay at the rate of 3.8 metric tons per hectare.

POST-TREATMENT SAMPLING

Soil

To evaluate the effects of the sludge treatments on the chemical properties of the soil, three pits were excavated on all plots four months after application on September 21, 1977. Each pit was opened to a depth of 75 cm. Soil samples were collected at the 0-15, 15-30, and 30-60 cm depth. These samples were analyzed for the same constituents as the pre-treatment soil samples to determine the first year effects of the sludge application on soil chemical properties. Soil samples were collected and analyzed to determine the second year effects of the sludge applications.

Vegetation

Vegetation growth responses were evaluated at the end of the growing season in 1977, 1978 and 1979. Measurements of vegetation height were taken at 10 locations along each of two transect lines in each sludge plot. Sampling points were approximately 7.5 meters apart on each transect line.

To determine dry matter production, twenty 0.1 square meter samples of the vegetative cover were collected in each of the sludge-treated plots. Four 0.1 square meter samples of vegetation were clipped along five transect

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lines in each area. The sampling points were 15 meters apart on transect lines spaced 15 meters apart.

Individual samples of each of the two grass and two legume species were collected from each sludge-treated plot for foliar analyses. Plant samples were prepared for analysis by oven-drying at 65°C for 48 hours and then ground in a Wiley mill to pass a 1 mm screen.

RESULTS

Soil Analysis

Results of the pre-treatment soil analyses are given in Appendix Tables A-1 and A-2. The values presented for each plot are the averages for samples collected in three soil pits. Considering the extreme variability normally found in spoil banks, the results indicate that pre-treatment soil content of Kjeldahl nitrogen, total sulfur, and Bray phosphorus were quite similar over the 4 hectare demonstration site. Soil acidity, expressed as pH, was also quite uniform except for the 1.0 hectare plot which subsequently received the low application rate (7 metric tons/ha) of liquid digested sludge. This portion of the spoil bank had received heavy applications of lime during previous attempts to revegetate the area. Heavy metal concentrations in the soil were all extremely low. Results of the pre- and post-treatment soil analyses for Kjeldahl nitrogen, total sulfur, and Bray phosphorus are given in Table 8 for the high application rate of each type of sludge. Results of post-treatment analyses for these constituents for all plots are given in Appendix Tables A-3 and A-4.

The amount of Bray phosphorus in the 0-15 cm soil depth was significantly increased initially by the 184 mt/ha sludge application and remained at a high level through the second year. Total sulfur was reduced at all depths following sludge applications. No significant change in Kjeldahl nitrogen was observed during the first four months; however, significant increases were noted during the second year particularly in the 0-15 cm depth. Nitrogen concentrations in the 0-15 cm depth were almost doubled 18 months after sludge application.

Results of the soil analyses for exchangeable cations for the limed and unlimed plots which received the highest sludge application (184 mt/ha dewatered sludge) are given in Table 9. Results for all plots are given in Appendix Tables A-5 and A-6. In general, the sludge applications increased the concentrations of calcium and decreased the concentrations of magnesium at all soil depths. Concentrations of potassium were not significantly changed. The lime application significantly increased the calcium concentration in the 0-15 cm soil depth.

It is not possible to make a direct comparison between the data from the control and sludge plots because of the inherent variability in the soil profile of such a disturbed site and the fact that the pre-treatment and post-treatment samples were not collected from the same pit. Thus, one can only interpret the data in terms of general trends.

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TABLE 8. ANALYSES OF SOIL SAMPLES COLLECTED ON THE VENANGO DEMONSTRATION PROJECT FOR KJELDAHL NITROGEN, TOTAL SULFUR, AND BRAY PHOSPHORUS

Sludge Application	Soil Depth	Sampling Date*	Kjeldahl Nitrogen	Total Sulfur	Bray Phosphorus
mt/ha	cm		%	%	µg/g
0	0-15	May 1977	0.04	0.16	2.00
	15-30	May 1977	0.05	0.20	1.80
	30-60	May 1977	0.05	0.25	1.97
11-Lime	0-15	Sept 1977	0.04	0.12	2.33
	15-30	Sept 1977	0.04	0.17	1.17
	30-60	Sept 1977	0.04	0.28	1.17
	0-15	Nov 1978	0.08	0.03	2.67
	15-30	Nov 1978	0.07	0.03	2.67
	30-60	Nov 1978	0.07	0.03	1.00
184-Lime	0-15	Sept 1977	0.05	0.08	11.17
	15-30	Sept 1977	0.04	0.07	3.67
	30-60	Sept 1977	0.06	0.07	3.00
	0-15	Nov 1978	0.09	0.07	9.00
	15-30	Nov 1978	0.06	0.10	3.67
	30-60	Nov 1978	0.07	0.10	1.33

* May 1977 samples represent pretreatment concentrations. September 1977 samples were collected four months after sludge application and November 1978 samples were collected 18 months after sludge application.

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TABLE 9. ANALYSES OF SOIL SAMPLES COLLECTED ON THE VENANGO COUNTY DEMONSTRATION PROJECT FOR EXCHANGEABLE CATIONS ON AREAS RECEIVING THE HIGHEST SLUDGE APPLICATION RATE

Sludge Application	Soil Depth	Sampling Date*	K	Ca	Mg
mt/ha	cm		- - - -	µg/g	- - - -
0	0-15	May 1977	12	541	452
	15-30	May 1977	12	535	579
	30-60	May 1977	13	936	910
184	0-15	Sept 1977	19	503	63
	15-30	Sept 1977	19	859	92
	30-60	Sept 1977	19	1817	130
	0-15	Nov 1978	27	780	64
	15-30	Nov 1978	27	1060	72
	30-60	Nov 1978	27	860	351
184-Lime	0-15	Sept 1977	19	1222	32
	15-30	Sept 1977	14	342	35
	30-60	Sept 1977	18	275	39
	0-15	Nov 1978	23	2600	40
	15-30	Nov 1978	23	746	32
	30-60	Nov 1978	23	446	40

* May 1977 samples represent pretreatment concentrations. September 1977 samples were collected four months after sludge application and November 1978 samples were collected 18 months after sludge application.

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Results of the analyses of the soil for extractable trace metals for the limed and unlimed plots which received the highest sludge application are given in Table 10. Trace metal concentrations in the 0-15 cm depth were higher on the lime treated plot. However, it should be noted that these concentrations were extremely low and were well below the normal range for Pennsylvania soils.

The effects of the highest application rates for both liquid and dewatered sludge on soil pH are shown in Table 11. After four months, soil pH at all depths was increased by all sludge application rates. Even though the liquid sludge application rate was low, it appears that it initially had a greater effect on soil pH, particularly at the greater depths. This was probably due to the fact that the liquid sludge percolated to greater soil depths. However, eighteen months after the sludge application, the soil pH dropped slightly. However, after 30 months the soil pH at the 0-15 and 15-30 cm depths were again at the initial high level. At the higher sludge application rate, 184 mt/ha, the soil pH at both the 0-15 and 15-30 cm depth continued to increase over the 30 month period to values of 7.3 and 5.1, respectively, by October 1979. Similar results were also observed for the 90 mt/ha sludge application. These results indicate that the sludge and lime applications did raise the soil pH significantly and that the higher pH was maintained for a 2.5 year period after treatment.

Effects of sludge applications on the concentrations of extractable iron, aluminum, and manganese and selected trace metals are given in Appendix Tables A-5 to A-8. Most significant changes occurred at the 0-15 cm depth. Results for the 0-15 cm soil depth for the highest sludge application (184 mt/ha) are given in Tables 12 and 13. Concentrations of iron, aluminum, and manganese all decreased significantly over time following the sludge application. All trace metal concentrations, except nickel, increased during the first four months following sludge application. No further significant increases were observed during the following 18 months. Even though trace metal concentrations increased in the 0-15 cm soil depth, the concentrations were still extremely low and within the normal range for Pennsylvania soils (Table 10).

Vegetation Growth Responses

Vegetation growth responses were evaluated at the end of each growing season in 1977, 1978, and 1979. Measurements of vegetation height were taken along transect lines in each treatment area. To determine dry matter production, twenty, 0.1-square meter samples of the vegetative cover were clipped in each treatment area. The results of these measurements are given in Table 14. All sludge-treated areas had a complete cover of vegetation by August 1977, three months after sludge application. Average height ranged from 29 to 35 cm, with the greatest growth being produced with the 184 mt/ha sludge application. Vegetation height continued to increase over the three growing seasons for sludge applications. During the first year there was no statistically significant difference in dry matter production between sludge types or application rates. However, the greatest dry matter production occurred with the 7 and 11 mt/ha liquid digested sludge application rates. As indicated earlier, these areas had previously received applications of lime

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TABLE 10. ANALYSES OF SOIL SAMPLES COLLECTED ON THE VENANGO COUNTY DEMONSTRATION PROJECT FOR EXTRACTABLE TRACE METALS ON AREAS RECEIVING HIGHEST SLUDGE APPLICATION RATE

Sludge Application	Soil Depth	Sampling Rate*	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha	cm					µg/g			
0	0-15	May 1977	2.5	2.9	0.2	0.5	0.7	0.02	1.1
	15-30	May 1977	3.0	2.4	0.1	0.6	0.7	0.02	1.0
	30-60	May 1977	3.7	3.6	0.2	0.9	1.0	0.03	1.6
184	0-15	Sept 1977	6.0	5.7	0.1	2.1	1.0	0.02	1.3
	15-30	Sept 1977	4.5	6.9	0.1	2.0	0.9	0.03	2.0
	30-60	Sept 1977	4.4	6.7	0.2	1.7	1.2	0.02	2.7
184-L	0-15	Sept 1977	10.8	7.7	0.4	3.5	1.3	0.04	0.9
	15-30	Sept 1977	4.0	2.0	0.1	1.3	0.2	0.01	0.4
	30-60	Sept 1977	4.9	2.9	0.1	1.9	0.3	0.01	0.5
Normal Range in Pennsylvania Soils			2-100	10-300	5-3000	2-200	1-40	0.01-7.00	5-500

* May samples represent pretreatment concentrations.
September samples were collected four months after sludge application.

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TABLE 11. CHANGES IN SOIL pH FOLLOWING SLUDGE APPLICATIONS AT THE VENANGO COUNTY DEMONSTRATION PROJECT

Sludge Application	Depth	Soil pH May* 1977	 Sept 1977	 Nov 1978	 Oct 1979
mt/ha	cm				
11-L	0-15	3.8	7.8	5.7	7.3
	15-30	3.8	6.7	4.5	6.1
90-L	0-15	3.8	6.6	6.6	7.7
	15-30	3.8	6.6	6.6	6.3
184-L	0-15	3.8	6.2	6.7	7.3
	15-30	3.8	4.2	4.6	5.1

* May values represent original spoil conditions.

TABLE 12. CHANGES IN CONCENTRATIONS OF SOIL EXTRACTABLE IRON, ALUMINUM, AND MANGANESE AT THE 0-15 CM DEPTH FOLLOWING SLUDGE APPLICATION AT 184 MT/HA AT THE VENANGO COUNTY DEMONSTRATION PROJECT

Sampling Date*	Fe	Al	Mn
		µg/g	
May 1977	40.3	186.3	4.7
Sept 1977	12.6	14.4	3.3
Nov 1978	18.7	7.3	4.0
Oct 1979	15.8	2.9	4.6

* May 1977 values represent pretreatment conditions.

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TABLE 13. CHANGES IN CONCENTRATIONS OF SOIL EXTRACTABLE TRACE METALS AT THE 0-15 CM DEPTH FOLLOWING SLUDGE APPLICATION AT 184 MT/HA AT THE VENANGO COUNTY DEMONSTRATION PROJECT

Sampling Date*	Cu	Zn	Cr	Pb	Co	Ni	Cd
				μg/g			
May 1977	2.5	2.9	0.2	0.5	0.7	1.1	0.02
Sept 1977	10.8	7.7	0.4	3.5	1.3	0.9	0.04
Nov 1978	8.8	7.7	0.2	2.3	1.2	1.2	0.02

* May 1977 values represent pretreatment conditions.

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TABLE 14. VEGETATION HEIGHT GROWTH AND DRY MATTER PRODUCTION FOR 1977, 1978 AND 1979 AT THE VENANGO COUNTY DEMONSTRATION PROJECT

Sludge Treatment	Height		
	1977	1978	1979
mt/ha		cm	
7	29	37	52
11	32	30	43
90-L	34	41	41
184-L	35	52	44
		Dry Matter Production	
		kg/ha	
7	6349	9537	18538
11	7731	8654	17141
90-L	4757	7409	13327
184-L	6013	9336	11322

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and fertilizer and had a sparse vegetative cover. The high dry matter production was probably due to the fact that the existing vegetation was not destroyed by scarification and growth was stimulated by the nutrients and water supplied by the liquid digested sludge. Due to the lack of rainfall and high temperatures during the early summer months (May and June), seed germination was delayed on the dewatered sludge treated plots until July. As a result, the first year dry matter production on these plots does not reflect a complete growing season.

It appears that even the low applications of liquid digested sludge supplied sufficient nutrients for vegetation establishment and growth during the first year. Dry matter production has significantly increased each year for all sludge application rates. During the second growing season the two grasses (tall fescue and orchardgrass) produced prolific seed heads. Seed heads were collected from 0.1 square meter plots and weighed. Results indicated a seed production ranging from 168 to 336 kg of seed per hectare.

During the first two growing seasons the two grass species were the dominant vegetation type on all sludge treated plots. By the third growing season the two legume species were well developed and had become the predominant vegetation cover on the plots treated with liquid digested sludge and the limed dewatered sludge treated plots. The unlimed dewatered sludge treated plots were still vegetated primarily by the two grass species with only a few sparse patches of legumes.

In general, the vegetative cover has improved over the three growing seasons following sludge application. No deterioration in vegetation quality or yield has been observed.

At the end of each growing season individual samples of the two grass and two legume species were collected from each sludge-treated area for foliar analyses. A few residual plants of tall fescue, orchardgrass, and birdsfoot trefoil from previous reclamation attempts were growing on the surrounding control area. Samples from these plants were also collected for comparison. Results of these analyses for each sludge application rate are given in Appendix, Tables A-9 to A-13. For discussion purposes the analyses for tall fescue and birdsfoot trefoil on the highest sludge-treated plots are given in Table 15 and 16. Species differences are obvious in that, in general, the legume had higher concentrations of nitrogen, calcium, and boron and the grass had higher concentrations of potassium and sodium (Table 15). For trace metals, concentrations were higher in the legume for all elements except chromium. For many of the constituents, higher foliar concentrations appeared to be associated with higher sludge application rates.

Results of the foliar analyses of tall fescue for trace metals indicated that many concentrations were higher on the control area than on any of the sludge-treated areas. This was probably due to soil pH. Surface soil pH on the control area was 3.8, whereas, on the sludge-treated areas, it ranged from 4.2 to 7.8. In general, foliar concentrations of trace metals in both the grass and legume species were lower the second and third growing season (1978 and 1979) after sludge application. For both grass and legume species, the results of the foliar analyses for trace metals also indicate that the

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TABLE 15. MEAN FOLIAR CONCENTRATIONS OF SELECTED CONSTITUENTS IN SAMPLES COLLECTED FROM THE CONTROL AND HIGHEST SLUDGE APPLICATION PLOTS AT THE VENANGO COUNTY DEMONSTRATION PROJECT

Sludge Application	Year	N	P	K	Ca	Mg	Mn	Fe	B	Al
mt/ha		%					μg/g			
		Tall Fescue								
0	1977	1.08	0.16	1.35	0.44	0.20	242	626	17	1000
	1978	2.73	0.23	1.95	0.93	0.31	63	553	10	213
184-L	1977	2.32	0.37	3.39	0.62	0.28	243	124	16	40
	1978	2.66	0.32	2.67	1.48	0.51	453	618	32	634
		Birdsfoot Trefoil								
0	1978	1.03	0.24	1.93	0.61	0.26	914	739	13	577
184-L	1977	3.64	0.27	1.46	1.99	0.28	165	93	54	50
	1978	1.27	0.36	2.30	0.59	0.25	527	158	9	106

lime treatment was not effective in further reducing the availability of these elements for uptake by the vegetation. In almost all cases, for both grass and legume species, the foliar trace metal concentrations were higher on the lime-treated plots. However, it should be noted that all trace metal concentrations are well below suggested tolerance levels and no phytotoxicity symptoms were observed (Council for Agricultural Science and Technology, 1976 and Melsted, 1973).

The predominant vegetation on all sludge-treated areas during the first year was the two grass species. A nitrogen budget was developed for the highest sludge application rate for each type of sludge and is given in Table 17. The amount of nitrogen available from the sludge was calculated on the basis of a 40 percent mineralization rate for the first year. On this basis, the nitrogen uptake by the vegetative cover accounted for over 100 percent of the available nitrogen supplied by the liquid sludge and 16 percent of that supplied by the dewatered sludge. There appears to be no common agreement on first-year sludge mineralization rates following land application. Values cited in the literature range from 10 to 40 percent. If one uses the lower mineralization rate, then the vegetation uptake of nitrogen becomes 425 and 62 percent of the available nitrogen supplied by the liquid and dewatered sludge, respectively.

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TABLE 16. MEAN FOLIAR CONCENTRATIONS OF TRACE METALS IN SAMPLES COLLECTED FROM THE CONTROL AND HIGHEST SLUDGE APPLICATION PLOTS AT THE VENANGO COUNTY DEMONSTRATION PROJECT

Sludge Application	Year	Cu	Zn	Cr	Pb	Co	Ni	Cd
mt/ha		----------	----------	-μg/g	----------	----------	----------	----------
				Tall Fescue				
0	1977	10.2	23.2	0.9	10.9	1.5	3.1	0.52
	1978	5.7	24.9	0.7	8.8	1.8	4.8	0.27
	1979	3.3	9.4	22.4	1.8	0.6	31.0	0.06
184-L	1977	9.4	48.4	0.8	4.5	1.5	9.8	0.20
	1978	8.6	44.4	0.8	4.5	1.6	3.7	0.41
	1979	9.2	72.5	0.5	1.8	0.6	2.5	0.08
				Birdsfoot Trefoil				
0	1978	7.7	32.2	0.3	8.6	2.6	7.4	0.14
	1979	8.4	38.0	8.5	2.6	0.6	21.4	0.10
184-L	1977	13.9	95.9	1.0	7.4	2.1	6.3	0.43
	1978	7.7	30.4	0.3	8.5	3.0	4.8	0.07
	1979	9.2	41.5	1.7	1.8	0.3	6.3	0.04
Suggested Tolerance Levels *, †		150	300	2	10	5	50	3

* Melsted (1973)

† Council for Agricultural Science and Technology (1976)

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TABLE 17. NITROGEN UTILIZATION BY THE VEGETATION DURING THE 1977 GROWING SEASON ON THE VENANGO COUNTY DEMONSTRATION PROJECT

Sludge Application	Sludge Type	DMP	Foliar N	Vegetation Uptake N	Sludge N Applied	Sludge N Available*	Vegetation Uptake N
mt/ha		kg/ha	%	kg/ha	kg/ha	kg/ha	%
11-L	Liquid	6903	1.75**	121	284	114	106
184-L	Dewatered	6013	2.47	149	2388	955	16

*Calculated at 40 percent mineralization rate.

**Average foliar nitrogen content for the two grass species.

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Percolate Water Quality

Results of the analyses of soil percolate water for the highest applications of both the liquid and dewatered sludge plots as well as the control plot are given in Tables 18, 19, and 20. Results of the analyses for all plots are given in Appendix, Tables A-14 to A-16. Average monthly concentrations of NO_3-N in the percolate during the summer months in the first year (1977) on the plots treated with the highest applications of dewatered sludge were only slightly above potable water standards (10 mg/l). The highest monthly average was 13.0 mg/l for the month of August. Percolate NO_3-N concentrations were surprisingly low during May and June immediately following the sludge application. This was probably due to the fact that rainfall during this period was below normal. As a result, there was little opportunity for leaching of nitrogen from the sludge to occur. By October, after development of a complete vegetative cover, the concentrations of NO_3-N in the percolate decreased to levels below 10 mg/l. Concentrations of NO_3-N in the percolate remained at low levels throughout 1978 and 1979. Highest concentration recorded in 1979 was 1.9 mg/l.

The average concentration of NO_3-N in each percolate water sample collected on the plots treated with dewatered sludge are plotted in Figures 3 to 6. As stated earlier little nitrate leaching occurred during June because of lack of rainfall. The greatest nitrate leaching occurred during the period of vegetation establishment (July and August). Once vegetation was established, the large uptake of NO_3-N by the growing vegetative cover resulted in a rapid decrease in the amount of NO_3-N available for leaching. The highest concentration recorded for any single sampling date was 24.5 mg/l.

Average monthly concentrations of NO_3-N in the percolate on the areas treated with liquid digested sludge were slightly higher than those measured on the dewatered sludge plots. The highest concentration was 33.9 mg/l on the 11 mt/ha plot and occurred during the first month (June, 1977) following sludge application. The highest concentration measured on the 7 mt/ha area was 16.5 mg/l in July. These higher concentrations were probably due in part to the fact that the NO_3-N concentration was higher in the liquid digested sludge (1780 ppm) than in the dewatered sludge (46 ppm) and nitrate-nitrogen in the liquid sludge is more susceptible to leaching prior to vegetation establishment. This is quite evident in Figures 7 and 8. Concentrations of NO_3-N in percolate water started to increase almost immediately after sludge application. By August, 1977 after development of a complete vegetative cover, concentrations of NO_3-N in percolate decreased to levels well below 10 mg/l and remained at low levels throughout 1978 and 1979.

The dewatered sludge applications did not have any significant effect on percolate pH during the 30 months following application.

Results of analyses of soil percolate water for selected cations for the control and highest sludge-treated plot are given in Tables 21 to 23. Results for all sludge-treated plots are given in Appendix, Tables A-17 to A-19. Concentrations of Mn, Al, K, Ca, Mg, and Na in percolate water at the 90 cm depth all increased following sludge application in 1977. Conversely,

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TABLE 18. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO COUNTY DEMONSTRATION PROJECT FOR 1977

Sludge Application	Month	Ortho P	NO_3-N	NH_4-N	Org-N	pH
mt/ha		mg/l				
0	May	0.075*	1.8	3.42	0.05	4.3
	June	0.158	2.8	1.27	0.05	3.4
	July	0.097	2.6	1.40	0.35	3.3
	Aug	0.033	1.2	1.18	1.70	3.4
	Sept	0.030	1.8	1.54	0.19	3.6
	Oct	0.020	1.9	1.24	1.19	3.7
	Nov	0.041	0.5	0.32	--	3.7
11-L	May	0.078	2.6	1.76	1.86	4.4
	June	0.044	33.9	14.07	--	4.4
	July	0.033	32.8	6.34	0.88	4.7
	Aug	0.032	4.9	1.90	0.49	5.0
	Sept	0.023	7.7	0.36	0.14	5.8
	Oct	0.014	2.3	0.18	0.28	5.6
	Nov	0.008	0.7	0.23	--	5.0
184-L	May	0.436	3.4	1.68	3.08	3.9
	June	0.294	2.4	4.44	--	3.2
	July	0.159	11.9	5.59	0.44	3.3
	Aug	0.082	13.0	5.90	--	3.4
	Sept	0.076	12.2	5.52	--	3.4
	Oct	0.043	7.5	3.00	--	3.6
	Nov	0.040	0.5	3.10	--	3.7

* Values are the means of all percolate samples collected during the month from the three lysimeters in each plot.

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TABLE 19. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO COUNTY DEMONSTRATION PROJECT FOR 1978

Sludge Application	Month	Ortho P	NO_3-N	NH_4-N	Org-N	pH
mt/ha				mg/l		
0	April	0.037	0.9	1.05	0.08	3.6
	May	0.029	0.9	1.01	0.15	3.8
	June	0.013	<0.5	0.87	--	4.2
	July	0.046	0.8	1.59	0.43	3.8
	Aug	0.036	0.7	1.55	0.53	3.6
	Sept	0.030	<0.5	2.30	0.38	2.6
	Oct	0.022	<0.5	2.02	0.19	4.2
	Nov	0.021	0.7	1.37	0.25	4.0
	Dec	0.020	<0.5	0.88	0.17	3.9
11-L	April	0.010	1.1	0.15	0.30	5.4
	May	0.007	1.3	0.24	0.20	5.0
	June	0.009	<0.5	0.22	0.21	5.4
	July	--	<0.5	--	--	5.0
	Aug	0.013	<0.5	0.14	0.28	4.7
	Sept	0.008	<0.5	0.15	0.49	3.8
	Oct	0.014	<0.5	0.18	0.31	3.6
	Nov	0.003	<0.5	0.13	0.12	4.2
	Dec	0.004	<0.5	0.12	0.23	4.3
184-L	April	0.018	<0.5	0.73	0.13	4.0
	May	0.023	<0.5	0.64	0.20	3.7
	June	0.022	<0.5	0.43	0.20	3.6
	July	0.031	0.7	0.63	0.47	3.8
	Aug	0.027	<0.5	0.14	0.28	3.7
	Sept	0.019	<0.5	0.15	0.41	3.5
	Oct	0.017	<0.5	0.16	0.23	3.4
	Nov	0.012	<0.5	0.14	0.23	3.6
	Dec	0.010	<0.5	<0.05	0.23	3.6

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TABLE 20. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO COUNTY DEMONSTRATION PROJECT FOR 1979

Sludge Application	Month	Ortho P	NO_3-N	NH_4-N	Org-N	pH
mt/ha				mg/l		
0	March	0.015	<0.5	0.73	0.08	4.1
	April	0.030	1.2	0.62	0.14	4.0
	May	0.020	0.7	0.78	0.41	4.0
	June	0.008	0.7	0.97	0.23	3.9
	July	0.026	<0.5	1.23	0.13	3.9
	Aug	0.019	<0.5	1.71	0.50	3.9
	Sept	0.020	<0.5	2.00	0.04	4.1
	Oct	0.032	0.9	1.41	0.20	3.8
11-L	March	0.001	<0.5	0.13	0.10	4.5
	April	0.010	<0.5	0.10	0.10	4.7
	May	0.023	<0.5	0.18	0.17	4.6
	June	0.014	<0.5	0.16	0.15	5.3
	July	--	<0.5	--	--	3.8
	Aug	0.075	1.0	0.48	--	3.3
	Sept	--	--	--	--	--
	Oct	0.157	0.8	0.48	0.39	3.7
184-L	March	0.003	<0.5	<0.05	0.11	3.9
	April	0.006	<0.5	0.07	0.11	3.9
	May	0.022	<0.5	0.07	0.13	3.7
	June	0.017	<0.5	0.09	0.15	3.8
	July	0.036	<0.5	0.09	0.19	3.5
	Aug	0.046	<0.5	0.11	0.35	3.4
	Sept	0.037	<0.5	0.27	0.25	3.5
	Oct	0.016	<0.5	0.10	0.21	3.6

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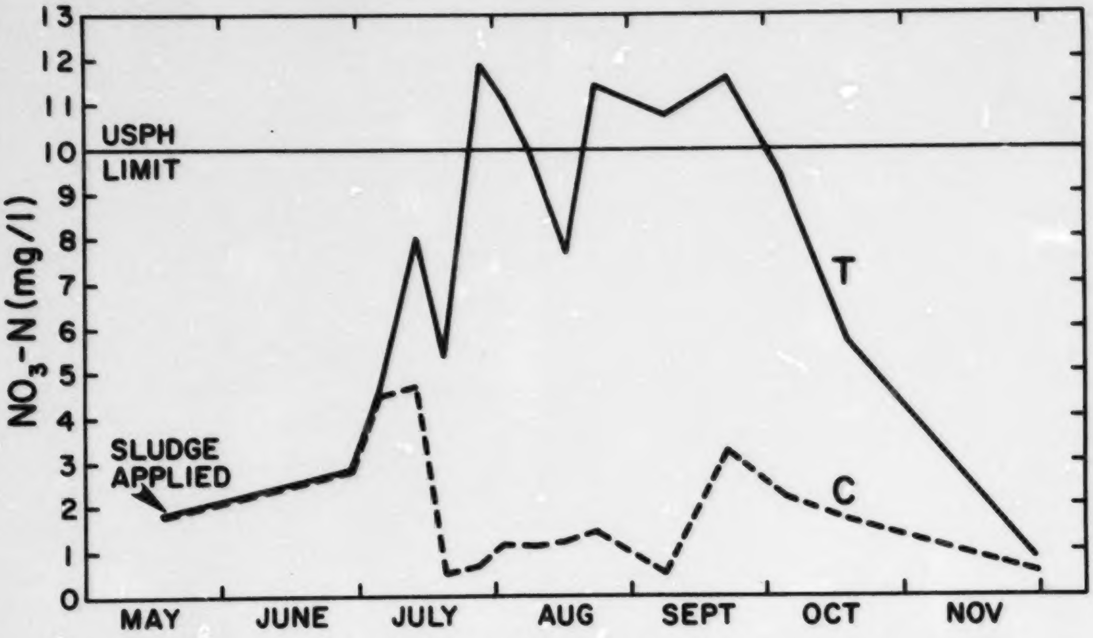

Figure 3. Concentration of NO_3-N in percolate water at the 90-cm soil depth on the plot treated (T) with dewatered sludge (184 mt/ha) and an adjacent control area (C).

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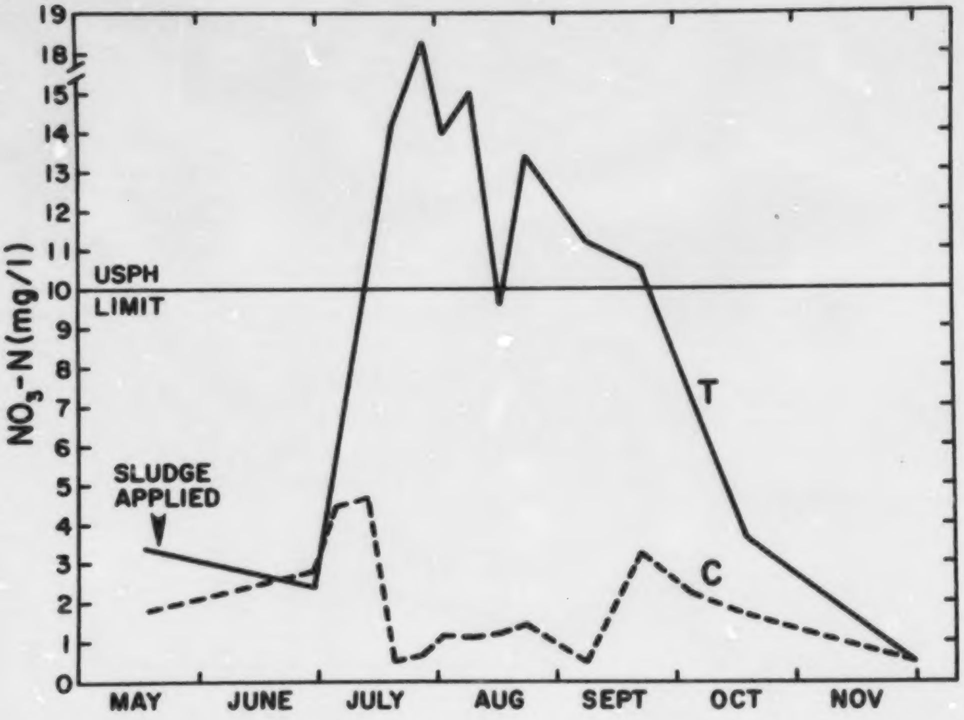

Figure 4. Concentration of NO_3-N in percolate water at the 90-cm soil depth for the plot treated with lime and dewatered sludge (184 mt/ha) and an adjacent control area.

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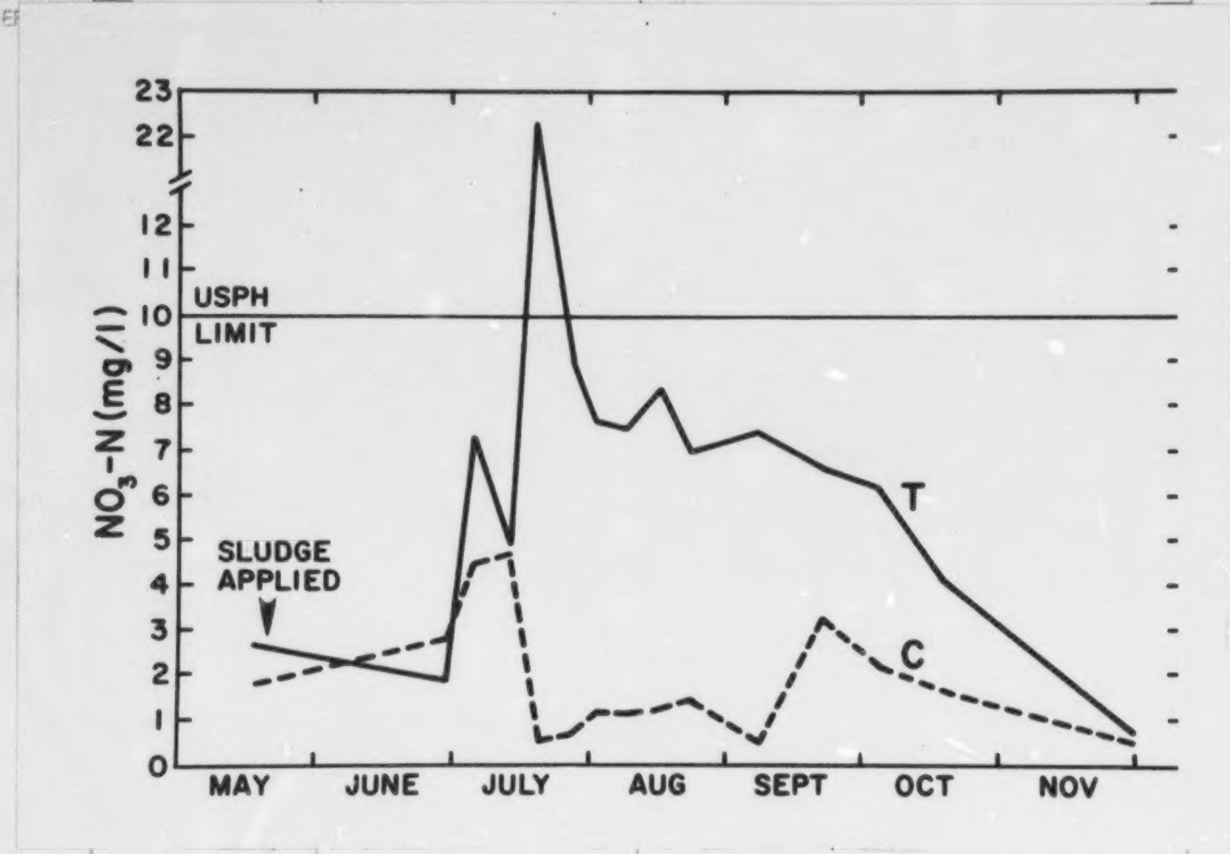

Figure 5. Concentration of NO_3-N in percolate water at the 90-cm soil depth for the plot treated with dewatered sludge (90 mt/ha) and an adjacent control area.

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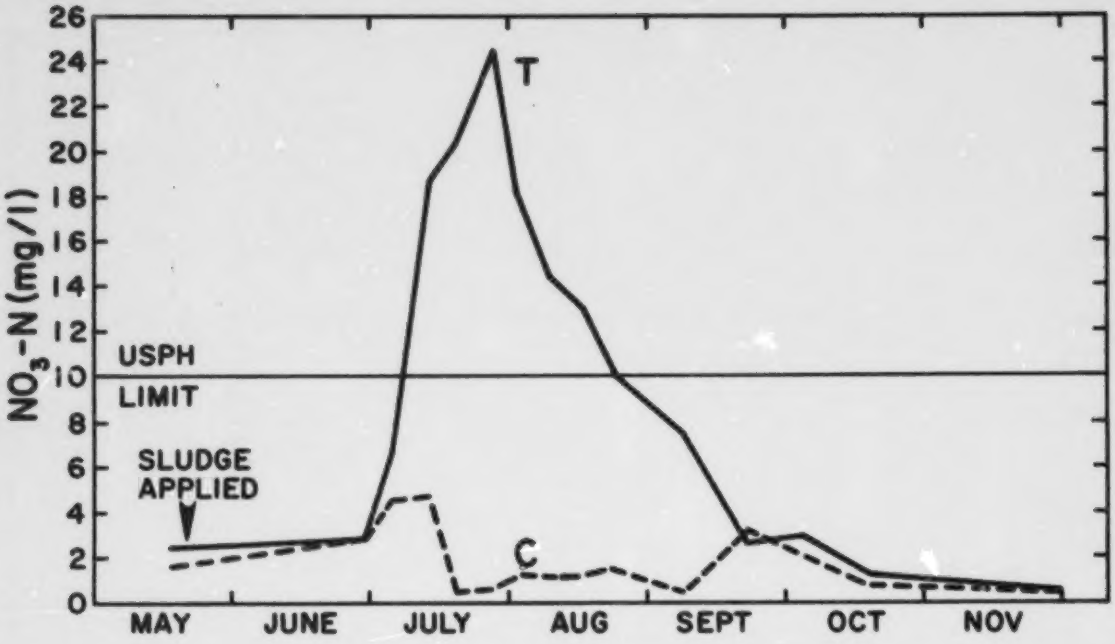

Figure 6. Concentration of NO_3-N in percolate water at the 90-cm soil depth for the plot treated with lime and dewatered sludge (90 mt/ha) and an adjacent control area.

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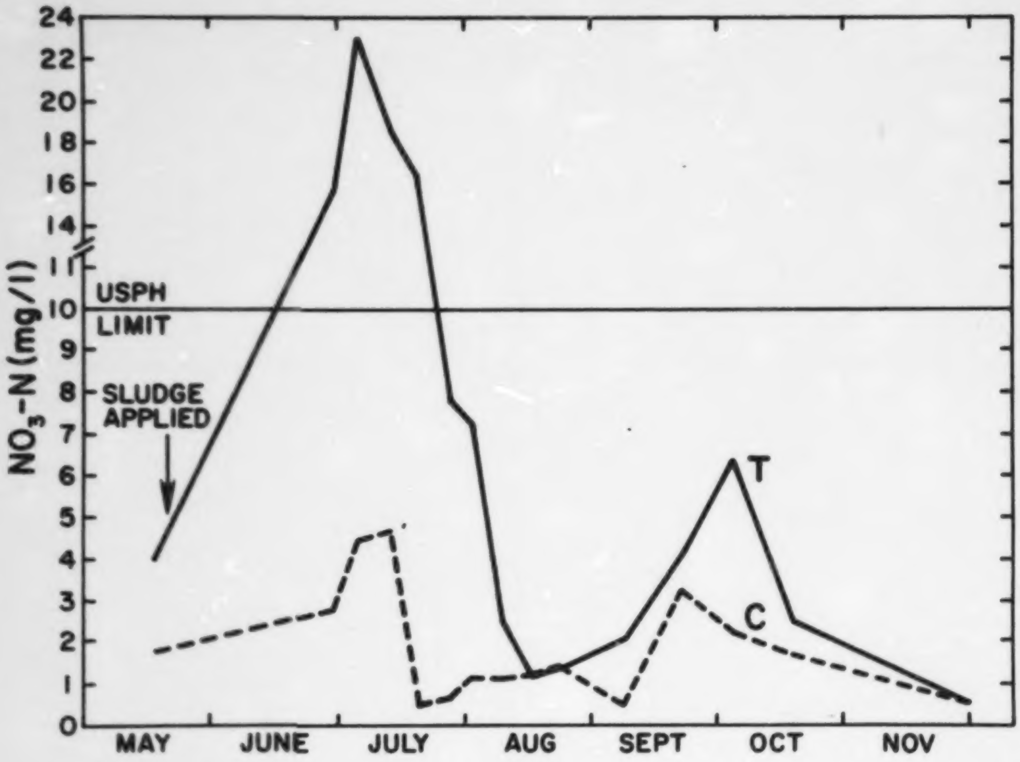

Figure 7. Concentration of NO_3-N in percolate water at the 90-cm soil depth for the plot treated with liquid digested sludge (7 mt/ha) and an adjacent control area.

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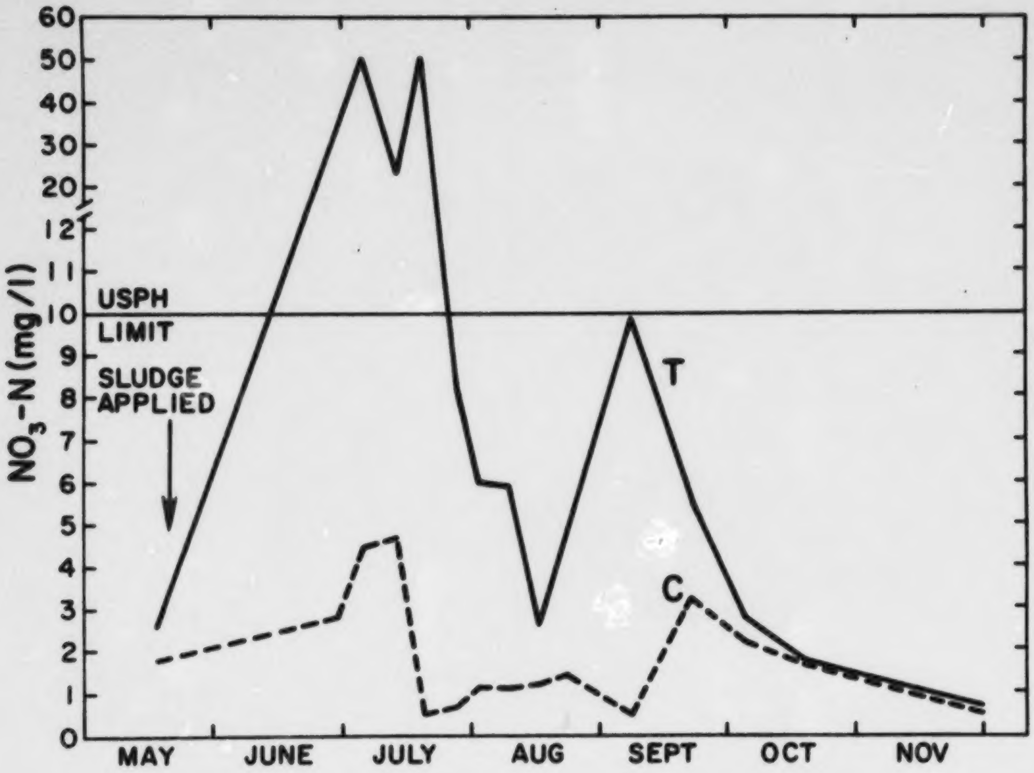

Figure 8. Concentration of NO_3-N in percolate water at the 90-cm soil depth for the plot treated with lime and liquid digested sludge (11 mt/ha) and an adjacent control area.

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TABLE 21. RESULTS OF ANALYSES FOR SELECTED CATIONS IN THE PERCOLATE WATER AT THE VENANGO COUNTY DEMONSTRATION PROJECT FOR 1977

Sludge Application	Month	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha		mg/l						
0	May	16.2	55.2	71.2	7.4	529.6	96.6	7.8
	June	65.7	29.6	193.9	2.8	591.4	354.7	5.6
	July	163.9	25.4	35.6	2.8	557.2	267.7	4.2
	Aug	29.1	18.7	28.2	2.3	370.5	63.7	3.8
	Sept	43.9	17.1	32.9	2.7	386.1	137.5	3.7
184-L	May	9.7	69.5	162.9	7.4	577.3	504.2	14.4
	June	1.9	68.1	181.3	3.0	585.4	466.9	9.7
	July	5.2	52.5	123.4	4.2	632.4	341.7	9.7
	Aug	0.8	30.0	52.1	5.3	586.8	110.7	8.0
	Sept	0.7	27.7	33.7	5.3	536.9	111.2	5.0

the concentration of Fe decreased. In 1978, the concentrations of all elements were lower on the sludge-treated plot in comparison to the control area. In the third year, 1979, the concentrations of all elements except Mg and Na were again higher on the sludge-treated plot. In general, over the three year period (1977-79), the concentrations of all elements except Fe decreased on both the control and sludge-treated plots.

Results of the analyses of soil percolate water for trace metals for all plots are given in Appendix, Tables A-20 to A-22. Concentrations of trace metals in the percolate on all sludge-treated plots were extremely low during all three years (Tables 24 to 26). There appears to be no significant increases in the concentrations of trace metals as a result of the sludge applications. Only slight increases in concentrations of zinc, nickel, and cobalt were observed during the first year in the percolate collected from the 184 mt/ha (lime) plot in comparison to the control plot. The results of the analyses also indicate that the lime application did not significantly reduce the concentrations of trace metals in the percolate any further than that found on sludge-treated plots without lime (Table 24).

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TABLE 22. RESULTS OF ANALYSES FOR SELECTED CATIONS IN THE PERCOLATE WATER AT THE VENANGO COUNTY DEMONSTRATION PROJECT FOR 1978

Sludge Application	Month	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha					mg/l			
0	April	85.8	4.9	63.2	2.6	203.2	68.9	2.8
	May	11.1	4.6	36.6	1.4	298.6	85.3	2.7
	June	5.9	3.6	17.9	3.0	297.9	75.0	3.4
	July	18.1	3.0	31.9	1.8	205.4	71.7	3.1
	Aug	53.0	3.9	59.3	2.2	255.1	94.8	3.4
	Sept	42.6	5.1	71.9	2.9	302.7	125.0	3.7
	Oct	30.1	3.8	59.8	2.0	268.9	104.3	3.3
	Nov	59.4	5.0	114.3	1.4	299.1	124.6	3.4
	Dec	3.2	1.8	26.2	1.1	212.7	68.6	3.0
184-L	April	1.1	3.2	14.0	7.8	226.5	24.4	2.2
	May	0.4	2.3	15.9	1.4	209.1	18.3	1.6
	June	0.1	1.6	9.8	0.8	168.9	13.2	1.2
	July	3.4	1.8	15.7	1.0	161.6	12.1	2.4
	Aug	16.3	2.6	15.0	1.2	157.9	17.4	3.5
	Sept	51.0	3.5	22.8	1.2	175.2	22.2	3.0
	Oct	23.3	2.8	17.8	1.2	160.8	17.8	3.7
	Nov	2.7	2.7	15.7	0.8	145.1	17.4	2.5
	Dec	0.3	2.3	12.5	0.7	137.6	15.2	2.3

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TABLE 23. RESULTS OF ANALYSES FOR SELECTED CATIONS IN THE PERCOLATE WATER AT THE VENANGO COUNTY DEMONSTRATION PROJECT FOR 1979

Sludge Application	Month	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha					mg/l			
0	March	16.8	2.3	36.2	1.0	194.8	70.7	2.9
	April	18.2	1.4	20.7	1.1	188.0	53.4	1.8
	May	16.4	1.5	21.7	1.1	188.5	42.2	2.0
	June	12.4	1.3	18.7	1.3	154.6	42.5	3.1
	July	10.7	1.5	23.5	1.9	156.9	50.0	2.3
	Aug	33.7	3.3	62.2	1.7	136.8	391.3	2.3
	Sept	36.5	4.4	70.8	5.9	216.3	48.2	2.8
	Oct	61.8	5.2	90.4	1.4	259.3	555.9	2.6
184-L	March	25.5	8.2	44.6	0.9	302.1	39.0	2.2
	April	32.3	7.2	32.2	1.3	311.7	36.0	1.6
	May	34.0	6.2	27.4	1.3	305.9	38.2	1.7
	June	47.7	5.4	23.1	1.3	316.5	34.7	1.7
	July	30.7	7.9	47.8	2.1	303.0	49.4	2.0
	Aug	32.5	1.6	9.4	2.0	72.9	8.6	2.1
	Sept	39.2	2.1	12.3	4.9	94.3	11.5	2.7
	Oct	10.3	1.8	9.5	2.3	98.0	11.7	2.1

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TABLE 24. SOIL PERCOLATE WATER ANALYSES FOR TRACE METALS AT THE VENANGO COUNTY DEMONSTRATION PROJECT DURING 1977

Sludge Application	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha					mg/l			
0	May*	1.98	7.44	0.75	0.18	1.95	0.006	4.09
	June	1.00	3.71	0.36	0.07	0.90	0.005	1.98
	July	0.86	3.37	0.32	0.07	0.75	0.006	1.53
	Aug	0.20	1.18	0.06	0.05	0.36	0.004	0.62
	Sept	0.20	1.33	0.08	0.08	0.32	0.005	0.63
	Oct	0.08	0.86	<0.01	0.01	0.23	0.004	0.37
	Nov	0.10	1.37	<0.01	0.06	0.18	0.004	0.38
11-L	May	0.16	3.87	0.05	0.06	1.46	0.009	2.58
	June	0.03	2.05	0.04	0.05	0.71	0.006	1.43
	July	0.03	2.60	<0.01	0.05	0.35	0.001	0.69
	Aug	0.04	0.38	<0.01	0.06	0.06	<0.001	0.11
	Sept	0.02	0.25	0.02	0.07	0.02	0.001	0.08
	Oct	<0.01	0.08	<0.01	0.01	0.02	<0.001	0.04
	Nov	0.01	0.22	<0.01	0.03	<0.01	<0.001	0.03
184	May	0.14	2.37	<0.01	0.05	1.07	0.008	1.72
	June	0.18	2.39	0.02	0.05	1.32	0.026	2.30
	July	0.16	3.74	0.02	0.05	0.87	0.009	1.53
	Aug	0.12	2.01	<0.01	0.05	0.76	0.005	1.26
	Sept	0.08	1.74	0.01	0.05	0.55	0.006	0.87
	Oct	0.05	1.32	<0.01	<0.01	0.42	0.006	0.69
	Nov	0.04	1.17	<0.01	<0.01	0.33	0.006	0.52
184-L	May	0.33	8.78	0.06	0.09	2.62	0.019	4.92
	June	0.45	9.55	0.07	0.05	2.53	0.015	5.31
	July	0.39	9.99	0.07	0.05	2.15	0.018	3.96
	Aug	0.23	4.61	0.02	0.07	1.30	0.005	2.38
	Sept	0.13	3.77	0.01	0.07	0.91	0.006	1.44
	Oct	0.09	2.31	<0.01	0.02	0.56	0.008	1.02
	Nov	0.06	2.33	0.01	0.03	0.41	0.006	0.74
USPHS Drinking Water Standards		1.0	5.0	0.05	0.05	5.0	0.01	2.0

*Values represent the mean of all samples collected from that plot for the month.

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TABLE 25. SOIL PERCOLATE WATER ANALYSES FOR TRACE METALS AT THE VENANGO COUNTY DEMONSTRATION PROJECT DURING 1978

Sludge Application	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha		mg/l						
0	April	0.27[*]	1.03	0.05	0.07	0.32	0.002	0.43
	May	0.11	0.62	0.03	0.06	0.22	0.002	0.26
	June	0.07	0.82	0.02	0.07	0.20	0.002	0.26
	July	0.11	1.04	0.01	0.14	0.16	0.002	0.27
	Aug	0.17	1.83	0.07	0.15	0.17	0.001	0.33
	Sept	0.17	2.73	0.09	0.12	0.32	0.002	0.38
	Oct	0.14	0.89	0.06	0.09	0.30	0.001	0.34
	Nov	0.15	1.11	0.07	0.13	0.21	0.002	0.50
	Dec	0.03	0.73	0.02	0.08	0.09	0.001	0.19
11-L	April	0.01	1.55	0.01	0.02	0.15	0.001	0.11
	May	0.01	0.45	<0.01	0.04	0.10	<0.001	0.12
	June	<0.01	0.14	<0.01	0.10	0.11	<0.001	0.21
	July	0.01	0.56	<0.01	0.15	0.04	<0.001	0.11
	Aug	0.29	2.93	0.03	0.17	0.33	0.001	0.39
	Sept	0.05	0.77	0.02	0.09	0.24	0.001	0.18
	Oct	0.01	0.31	0.02	0.08	0.11	0.001	0.13
	Nov	<0.01	0.15	0.01	0.07	0.10	0.001	0.08
	Dec							
184-L	April	0.03	1.82	<0.01	<0.01	0.27	0.002	0.27
	May	0.03	1.31	<0.01	<0.01	0.18	0.001	0.25
	June	0.02	0.71	<0.01	0.08	0.14	0.001	0.26
	July	0.06	1.28	<0.01	0.12	0.13	0.001	0.22
	Aug	0.06	1.42	<0.01	0.13	0.18	0.002	0.32
	Sept	0.09	1.18	<0.01	0.12	0.24	0.002	0.36
	Oct	0.06	1.21	0.01	0.10	0.27	0.002	0.27
	Nov	0.02	0.75	0.01	0.07	0.14	0.002	0.22
	Dec	0.01	0.76	<0.01	0.04	0.13	0.001	0.21
USPHS Drinking Water Standards		1.0	5.0	0.05	0.05	5.0	0.01	2.0

[*] Values represent the mean of all samples collected from that plot for the month.

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TABLE 26. SOIL PERCOLATE WATER ANALYSES FOR TRACE METALS AT THE VENANGO COUNTY DEMONSTRATION PROJECT DURING 1979

Sludge Application	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha					mg/l			
0	March	0.08	0.37	0.04	0.06	0.09	<0.001	0.21
	April	0.06	0.35	0.02	0.04	0.10	<0.001	0.20
	May	0.06	0.31	0.02	0.05	0.07	<0.001	0.15
	June	0.05	0.35	0.03	0.03	0.06	<0.001	0.11
	July	0.06	0.47	0.03	0.04	0.09	<0.001	0.12
	Aug	0.14	0.98	0.06	0.09	0.18	<0.001	0.38
	Sept	0.14	1.33	0.09	0.06	0.22	<0.001	0.51
	Oct	0.20	1.28	0.08	0.04	0.16	0.001	0.41
11-L	March	0.01	0.15	0.01	0.02	0.04	<0.001	0.09
	April	0.01	1.10	<0.01	0.03	0.08	0.001	0.05
	May	<0.01	0.28	<0.01	0.03	0.02	<0.001	0.06
	June	<0.01	0.26	0.02	0.11	0.03	<0.001	0.06
	July	--	--	--	--	--	--	--
	Aug	--	--	--	--	--	--	--
	Sept	--	--	--	--	--	--	--
	Oct	0.47	2.52	0.04	0.13	0.42	0.005	0.66
184-L	March	0.09	0.80	0.02	0.06	0.27	0.001	0.53
	April	0.08	1.17	0.02	0.08	0.27	0.001	0.41
	May	0.06	0.69	0.02	0.01	0.22	0.001	0.32
	June	0.04	0.66	0.01	0.07	0.16	0.002	0.30
	July	0.15	1.33	0.04	0.06	0.36	0.001	0.48
	Aug	0.05	0.66	0.01	0.04	0.12	<0.001	0.23
	Sept	0.05	0.95	0.01	0.03	0.13	<0.001	0.29
	Oct	0.03	0.69	<0.01	0.03	0.06	0.001	0.14
USPHS Drinking Water Standards		1.0	5.0	0.05	0.05	5.0	0.01	2.0

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Results indicate that percolate water quality met USPHS drinking water standards with only a few exceptions. During the first three months in the first year following sludge application, the concentrations of Zn and Ni significantly increased and exceeded drinking water standards at the highest sludge application rate (184-L mt/ha). Concentrations of Cr and Pb slightly exceeded drinking water standards on both the control and sludge-treated plots. During the second (1978) and third (1979) year only concentrations of Pb exceeded drinking water standards at the highest sludge applications. These concentration increases were minimal and pose no threat to human or animal health. It should also be noted that the average monthly concentrations of Pb on the control plot also exceeded potable water standards during 1978 and 1979.

Total and fecal coliform analyses were conducted on all soil percolate water samples collected during the period May, 1977 through October, 1979. No fecal coliform colonies were observed for any sample.

Groundwater Quality

Results of the analyses of groundwater well samples are given in Tables 27,to 30 and in Appendix Tables A-23 to A-25. Well 1 was drilled as a control outside the area of influence of the sludge applications. The values presented for Well 1 reflect the general groundwater quality for the disturbed mine site. Groundwater flow under the sludge-treated areas is toward Wells 2 and 3, with Well 2 reflecting the effect of the dewatered sludge applications and Well 3 reflecting the effect of the liquid digested sludge applications on groundwater quality. During the three year period of measurement the depth to the water table fluctuated in Well No. 1 from 4.4 to 5.3 m, in Well No. 2 from 2.5 to 3.4 m and in Well No. 3 from 1.3 to 2.4 m. Results indicate that the sludge applications have not had any significant effect on groundwater concentrations of orthophosphate-P, NO_3-N, NH_4-N or Org-N. Average monthly concentrations of NO_3-N were below 10 mg/l for all months sampled during the three year period (1977-79) (Table 27). Concentrations of NO_3-N in each groundwater sample collected during 1977 are shown in Figures 9 to 11. The only significant effect was the short-lived increases in NO_3-N concentration in the groundwater influenced by the liquid digested sludge applications. This peak is correlated with the increased NO_3-N concentrations in the percolate water. It should also be noted that percolate water samples are collected at the 90-cm soil depth and the average depth to the groundwater table in Well No. 3 is only 180 cm during the summer. Results from Well 2 indicate that the applications of dewatered sludge did not significantly change groundwater pH during the first 15 months. The high pH values found in Well 3 were not due to the liquid sludge applications, but rather, reflect pretreatment conditions. The soil in the vicinity of this well initially had a high pH ranging from 6.2 to 7.5.

Results of analyses of groundwater samples for trace metals for 1977, 1978 and 1979 are given in Tables 28, 29 and 30. There appears to be no significant increase in any of the trace metal concentrations over the three-year period in either well (Well 2 and 3) influenced by the sludge applications. Most of the concentrations were below the USPHS drinking water standards.

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TABLE 27. GROUNDWATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO COUNTY DEMONSTRATION PROJECT FOR 1977, 1978, AND 1979

Well No. and Month	Year	Ortho P	NO_3-N	NH_4-N	Org-N	pH
		- - - - - - - - - -	- - - -	mg/1	- - - - - -	- - - -
Well 1 (Control)						
June	1977	0.004	3.0	0.46	1.22	4.0
July		0.021	1.6	2.89	0.44	4.0
Aug		0.004	1.2	0.91		4.0
Sept		0.008	1.0	1.27		4.2
Oct		0.018	0.8	0.85		4.6
Nov		0.027	0.5	2.70		5.4
March	1978	0.033	0.5	2.60	1.80	4.4
April		0.006	0.5	2.29	0.91	5.0
May		0.009	0.5	2.20	1.00	5.4
June		0.002	0.5	2.20	1.20	4.4
July		0.006	0.5	0.05	0.00	5.2
Aug		0.012	0.5	2.00	2.80	4.0
Sept		0.003	0.5	3.00	0.30	3.0
Oct		<0.001	0.5	3.02	0.00	3.0
Nov		<0.001	0.5	2.10	1.60	4.3
Dec		0.003	0.5	1.25	0.85	4.6
March	1979	<0.001	0.5	0.25	2.65	4.2
April		<0.001	0.5	2.80	0.20	3.8
May		<0.001	0.5	2.60	0.80	4.5
June		0.007	0.5	2.70	0.70	4.8
July		0.002	0.5	2.30	0.00	5.4
Aug		<0.001	0.5	2.80	0.50	4.1
Sept		0.090	0.5	2.60	0.20	4.3
Oct		0.008	0.5	2.70	0.40	5.4

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TABLE 27. (continued)

Well No. and Month	Year	Ortho P	NO_3-N	NH_4-N	Org-N	pH
		mg/l				
Well 2 (Dewatered Sludge)						
June	1977	0.004	2.4	0.41	1.11	4.1
July		0.052	1.4	0.47	0.27	4.5
Aug		0.006	1.2	0.53	0.17	4.5
Sept		0.003	0.5	0.32		4.5
Oct		0.016	0.8	0.35		5.1
Nov		0.012	0.5	0.60		5.0
March	1978	0.035	0.5	0.50	0.39	4.5
April		0.006	0.5	0.58	0.02	5.4
May		0.006	0.5	0.45	0.47	5.8
June		0.000	0.5	0.62	0.22	5.4
July		0.012	0.5	0.05	0.00	5.4
Aug		0.012	0.5	0.43	0.41	4.6
Sept		<0.001	0.5	0.38	0.24	3.1
Oct		0.006	0.5	0.63	0.19	2.8
Nov		<0.001	0.5	0.81	0.33	4.1
Dec		<0.001	0.5	0.43	0.29	4.2
March	1979	<0.001	0.5	0.57	0.19	4.5
April		<0.001	0.5	0.61	0.11	3.3
May		<0.001	0.5	0.58	0.20	4.9
June		0.004	0.5	0.65	0.21	4.9
July		<0.001	0.5	0.56	0.24	4.7
Aug		<0.001	0.5	0.63	0.33	3.7
Sept		<0.001	0.5	0.66	0.30	4.3
Oct		<0.001	0.5	0.71	0.09	4.8

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TABLE 27. (continued)

Well No. and Month	Year	Ortho P	NO_3-N	NH_4-N	Org-N	pH
		mg/l				
Well 3 (Liquid Sludge)						
June	1977	0.015	7.0	0.24	1.96	7.6
July		0.029	7.0	0.05	0.39	6.5
Aug		0.198	1.2	0.06	0.41	6.2
Sept		0.023	0.9	0.11	0.20	6.3
Oct		0.041	1.9	0.05	0.29	6.5
Nov		0.009	0.5	0.05		6.5
March	1978	0.012	0.5	0.05	0.31	6.3
April		0.006	0.5	0.05	0.19	6.3
May		0.000	0.5	0.05	0.41	6.4
June		0.000	0.5	0.10	0.20	6.6
July		0.012	0.5	0.05	0.19	6.4
Aug		0.064	0.5	0.05	0.39	6.5
Sept		0.003	0.5	0.05	0.27	7.1
Oct		0.006	0.5	0.05	0.31	7.0
Nov		0.002	0.5	0.05	0.23	7.8
Dec		<0.001	0.5	0.05	0.13	6.7
March	1979	<0.001	1.0	0.05	0.13	7.9
April		<0.001	0.5	0.05	0.19	6.5
May		<0.001	0.5	0.05	0.29	6.5
June		0.004	0.5	0.05	0.19	6.5
July		0.002	0.5	0.05	0.21	6.5
Aug		<0.001	0.5	0.05	0.33	7.3
Sept		<0.001	0.5	0.05	0.31	6.1
Oct		<0.001	0.5	0.05	0.27	5.7

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TABLE 28. GROUNDWATER ANALYSES FOR TRACE METALS AT THE VENANGO COUNTY DEMONSTRATION PROJECT DURING 1977

Well No.	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
		mg/l						
Well 1 (Control)	July	0.18	5.80	<0.01	0.08	3.35	0.007	4.57
	Aug	0.31	4.57	0.04	0.08	3.40	0.006	4.53
	Sept	0.21	3.92	0.01	0.16	3.12	0.006	3.54
	Oct	0.33	4.77	0.02	0.15	3.54	0.007	3.49
	Nov	0.09	1.57	<0.01	0.21	2.53	0.002	2.22
Well 2 (Dewatered Sludge)	July	0.18	4.13	<0.01	0.08	2.44	0.001	2.96
	Aug	0.06	3.62	0.03	0.05	2.65	0.001	3.28
	Sept	0.10	3.03	0.09	0.13	1.72	0.001	2.56
	Oct	0.05	3.29	0.02	0.07	2.10	0.001	2.81
	Nov	0.09	2.86	<0.01	0.14	1.71	0.001	1.72
Well 3 (Liquid Sludge)	July	1.00	0.19	<0.01	0.07	0.01	<0.001	0.01
	Aug	1.06	0.09	0.02	0.07	0.04	<0.001	0.02
	Sept	1.06	0.18	0.01	0.12	0.01	0.001	0.45
	Oct	1.24	0.09	0.01	0.11	0.04	<0.001	0.06
	Nov	0.09	0.08	<0.01	0.04	0.02	<0.001	0.05

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TABLE 29. GROUNDWATER ANALYSES FOR TRACE METALS AT THE VENANGO COUNTY DEMONSTRATION PROJECT DURING 1978

Well No.	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
		mg/l						
Well 1 (Control)	March	0.27	0.15	<0.01	0.05	0.06	0.001	0.10
	April	0.50	4.49	0.01	0.28	1.47	0.003	1.18
	May	0.15	0.98	0.01	0.16	1.47	0.001	0.93
	June	0.30	2.37	0.01	0.17	1.76	0.001	1.07
	July	0.10	1.52	<0.01	0.20	1.11	0.001	1.05
	Aug	0.30	2.82	<0.01	0.28	0.98	0.003	1.36
	Sept	0.26	2.52	0.01	0.26	0.90	0.003	1.04
	Oct	0.33	3.36	0.01	0.20	1.67	0.004	2.29
	Nov	<0.01	0.39	<0.01	0.09	0.37	0.001	0.25
	Dec	0.11	1.59	0.01	0.23	0.62	0.002	0.51
Well 2 (Dewatered Sludge)	March	--	--	--	--	--	--	--
	April	0.12	2.96	0.01	0.33	1.31	0.002	0.98
	May	0.16	0.84	0.01	0.14	1.23	0.001	0.75
	June	0.07	10.72	0.03	0.22	1.50	0.004	1.17
	July	0.11	1.79	<0.01	0.18	0.91	0.001	1.13
	Aug	0.24	3.61	<0.01	0.28	1.01	0.001	1.52
	Sept	0.27	2.79	0.01	0.11	0.85	0.001	1.19
	Oct	0.17	2.50	0.01	0.26	1.13	0.001	1.45
	Nov	0.01	2.01	0.01	0.11	1.27	0.001	1.68
	Dec	0.12	2.41	<0.01	0.17	1.26	0.002	1.49
Well 3 (Liquid Sludge)	March	0.57	0.59	0.01	0.25	1.02	0.001	0.59
	April	0.09	0.24	0.01	0.28	0.14	0.001	0.12
	May	0.13	0.33	0.01	0.09	0.22	0.001	0.01
	June	0.08	0.52	0.02	0.16	0.18	0.001	0.13
	July	0.22	1.58	<0.01	0.11	<0.01	0.001	0.04
	Aug	0.92	0.23	0.05	0.22	0.36	<0.001	0.24
	Sept	0.78	0.40	<0.01	0.16	0.06	<0.001	0.01
	Oct	0.33	0.38	0.01	0.20	0.11	<0.001	0.01
	Nov	<0.01	0.31	<0.01	0.06	0.05	<0.001	0.03
	Dec	0.05	0.29	0.01	0.06	0.03	0.001	0.01

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TABLE 30. GROUNDWATER ANALYSES FOR TRACE METALS AT THE VENANGO COUNTY DEMONSTRATION PROJECT DURING 1979

Well No.	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
		mg/l						
Well 1 (Control)	March	0.05	0.97	0.04	0.11	0.48	0.001	0.29
	April	0.28	1.05	0.04	0.18	0.51	0.001	0.42
	May	0.10	0.99	0.04	0.13	0.60	0.003	0.45
	June	0.19	1.25	0.04	0.13	0.70	0.001	0.52
	July	0.36	2.20	0.04	0.17	0.71	0.002	0.46
	Aug	0.18	2.69	0.02	0.14	0.66	0.001	1.15
	Sept	0.15	2.02	0.03	0.09	0.58	0.002	0.40
	Oct	0.04	0.70	0.02	0.09	0.36	0.001	0.28
Well 2 (Dewatered Sludge)	March	0.14	1.22	0.03	0.12	1.30	0.001	1.12
	April	0.33	0.98	0.03	0.16	1.14	0.001	0.98
	May	0.04	0.43	0.02	0.08	1.24	0.001	1.06
	June	0.21	0.85	0.03	0.12	1.34	0.001	1.03
	July	0.36	1.85	0.03	0.14	1.32	0.001	1.14
	Aug	0.14	2.52	0.02	0.18	1.16	0.001	0.39
	Sept	0.09	2.36	0.03	0.22	1.08	0.001	1.15
	Oct	0.09	1.75	0.01	0.04	6.77	0.001	0.88
Well 3 (Liquid Sludge)	March	0.03	0.53	0.02	0.06	0.05	0.001	0.02
	April	0.21	0.34	0.02	0.12	0.05	0.001	<0.01
	May	0.02	0.01	0.01	0.03	0.07	0.003	<0.01
	June	0.10	0.21	0.01	0.08	0.01	0.001	<0.01
	July	0.21	0.50	0.01	0.04	<0.01	0.001	0.01
	Aug	0.06	0.61	0.01	0.08	<0.01	<0.001	0.38
	Sept	0.06	1.07	0.01	<0.01	0.02	0.001	0.06
	Oct	0.01	0.22	<0.01	0.03	0.02	<0.001	0.03

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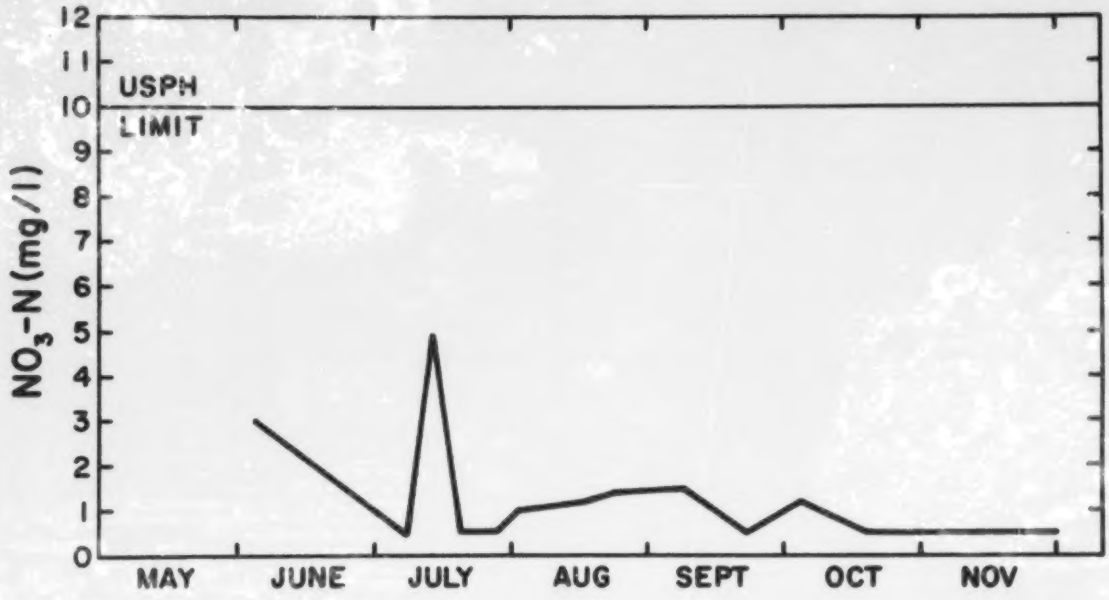

Figure 9. Concentration of NO_3-N in groundwater monitoring well on control area during 1977.

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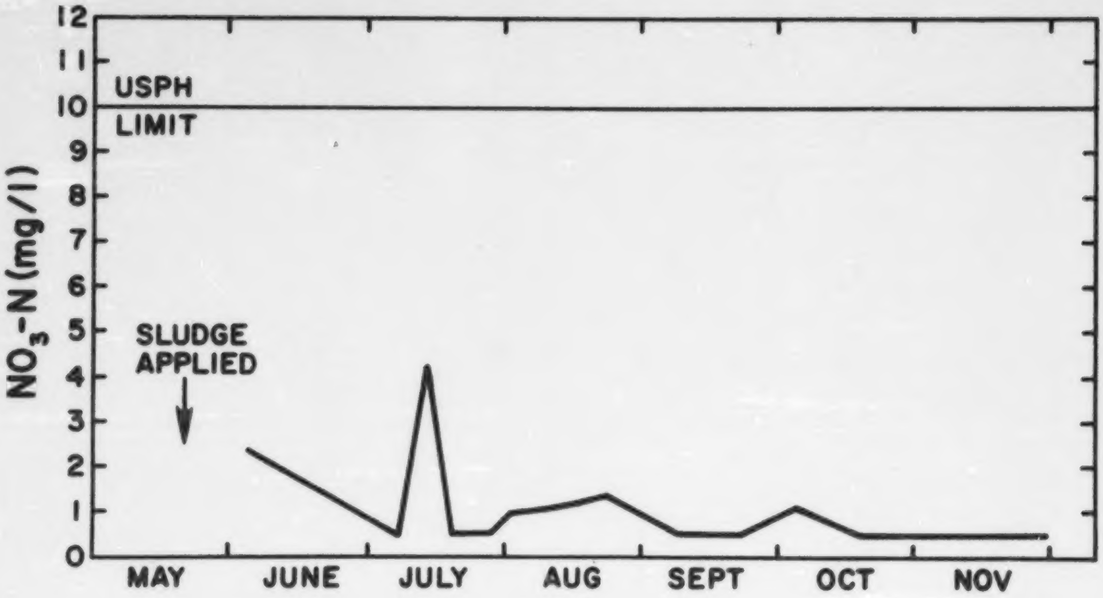

Figure 10. Concentration of NO_3-N in groundwater monitoring well influenced by the dewatered sludge applications during 1977.

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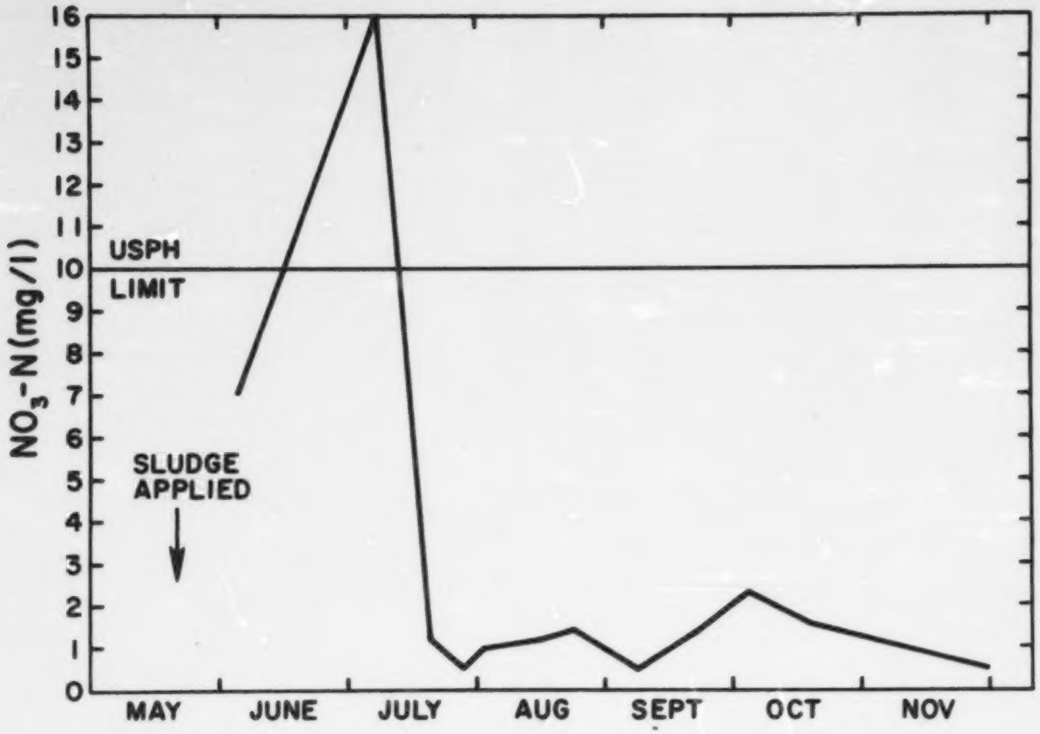

Figure 11. Concentrations of NO_3-N in the groundwater monitoring well influenced by the liquid digested sludge applications during 1977.

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For comparison, these standards are:

Element:	Maximum Allowable Concentration (mg/l)
Cu.	1.0
Zn.	5.0
Cr.	0.05
Pb.	0.05
Cd.	0.01
Co*/.	5.0
Ni*/.	2.0

The only element which exceeded drinking water standards was Pb. During all three years most of the monthly groundwater samples collected on both the control and sludge-treated plots had Pb concentrations higher than 0.05 mg/l.

Total and fecal coliform analyses were conducted on groundwater samples collected during the period July, 1977 through October, 1979. No total or fecal coliform colonies were observed for any sample.

Lake Water Quality

The results of lake water sample analyses are given in Table 31. Concentrations of NO_3-N in each lake sample collected during 1977 are plotted in Figures 12 and 13. A slight increase in NO_3-N concentration is evident in Lake No. 1 immediately after sludge application. This lake is in close proximity to the liquid digested sludge application plots and this increase may have been due to some surface runoff of sludge during initial rainfall events prior to vegetation establishment. However, the border area around the sludge-treated plots was scarified with a chisel plow and no evidence of sludge runoff was observed. Another possible explanation is that a portion of the groundwater flow under the sludge treated plot is toward the lake as well as toward Well No. 3. This explanation is quite feasible because the groundwater table is so high (180 cm) and the sludge-treated plot is located on a topographic high point with surface topography sloping toward both the well and the lake.

Results of analyses for Cu, Zn, and Cd in lake water samples collected in 1977, 1978, and 1979 are given in Tables 32 to 34. All values were below drinking water standards. Results of analyses of lake water samples for selected constituents are given in Appendix, Tables A-26 to A-28.

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*/ No limits given for drinking water standards; these are recommended values for irrigation water for agricultural use.

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TABLE 31. LAKE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO COUNTY DEMONSTRATION PROJECT DURING 1977, 1978, AND 1979

Lake No. and Month	Year	Ortho P	NO_3-N	NH_4-N	Org-N	pH
		- - - - - - - - -	mg/l	- - - - - - - - -		
Lake 1						
May	1977	0.005	2.8	0.05	0.82	5.1
June		0.017	0.5	0.05	0.09	3.8
July		0.021	1.9	0.11	0.07	3.6
Aug		0.007	1.2	0.17	1.73	3.7
Sept		0.002	0.9	0.16	0.20	3.8
Oct		0.003	1.1	0.18	0.34	4.1
Nov		0.002	0.5	0.05	0.39	4.4
April	1978	0.000	0.5	0.10	0.46	5.2
May		0.000	0.5	0.05	0.15	6.2
June		0.009	0.5	0.12	0.12	4.3
July		0.012	0.5	0.05	0.17	4.0
Aug		0.005	1.0	0.05	0.15	3.9
Sept		0.006	0.5	0.05	0.11	3.8
Oct		0.003	0.5	0.05	0.15	3.8
Nov		0.002	0.5	0.23	0.01	4.2
Dec		<0.001	0.5	0.29	0.01	4.0
Mar	1979	<0.001	0.5	0.05	0.17	5.4
Apr		<0.001	0.5	0.05	0.07	4.7
May		<0.001	0.5	0.05	0.11	4.7
June		0.004	0.5	0.05	0.17	4.4
July		0.002	0.5	0.05	0.25	4.0
Aug		0.001	0.5	0.05	0.32	3.7
Sept		<0.001	0.5	0.05	0.17	3.5
Oct		0.002	0.5	0.05	0.21	3.7

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TABLE 31. (continued)

Lake No. and Month	Year	Ortho P	NO_3-N	NH_4-N	Org-N	pH
		- - - - - - - - - mg/l	- - - -	- - - -	- - - -	- - - -
Lake 2						
May	1977	0.008	1.3	0.05	0.20	6.8
June		0.026	0.5	0.05	0.17	6.1
July		0.019	1.3	0.05	0.28	6.7
Aug		0.016	1.2	0.07	0.19	6.2
Sept		0.003	0.5	0.11	0.24	6.5
Oct		0.008	0.5	0.07	0.41	6.8
Nov		0.040	0.5	0.05	0.31	6.2
April	1978	0.009	0.5	0.05	0.31	6.5
May		0.000	0.5	0.05	0.27	6.9
June		0.000	0.5	0.05	0.23	6.1
July		0.006	0.5	0.05	0.43	7.1
Aug		0.008	0.5	0.05	0.37	6.5
Sept		0.012	0.5	0.05	0.33	6.6
Oct		<0.001	0.5	0.05	0.23	6.8
Nov		0.008	0.5	0.05	0.23	6.8
Dec		0.006	0.5	0.05	0.27	6.8
Mar	1979	<0.001	0.5	0.05	0.19	6.8
Apr		<0.001	0.5	0.05	0.15	6.5
May		0.004	0.5	0.05	0.15	6.2
June		<0.001	0.5	0.05	0.25	6.4
July		0.005	0.5	0.05	0.25	6.4
Aug		<0.001	0.5	0.05	0.89	7.4
Sept		<0.001	0.5	0.05	0.37	6.7
Oct		0.020	0.5	0.05	0.55	7.4

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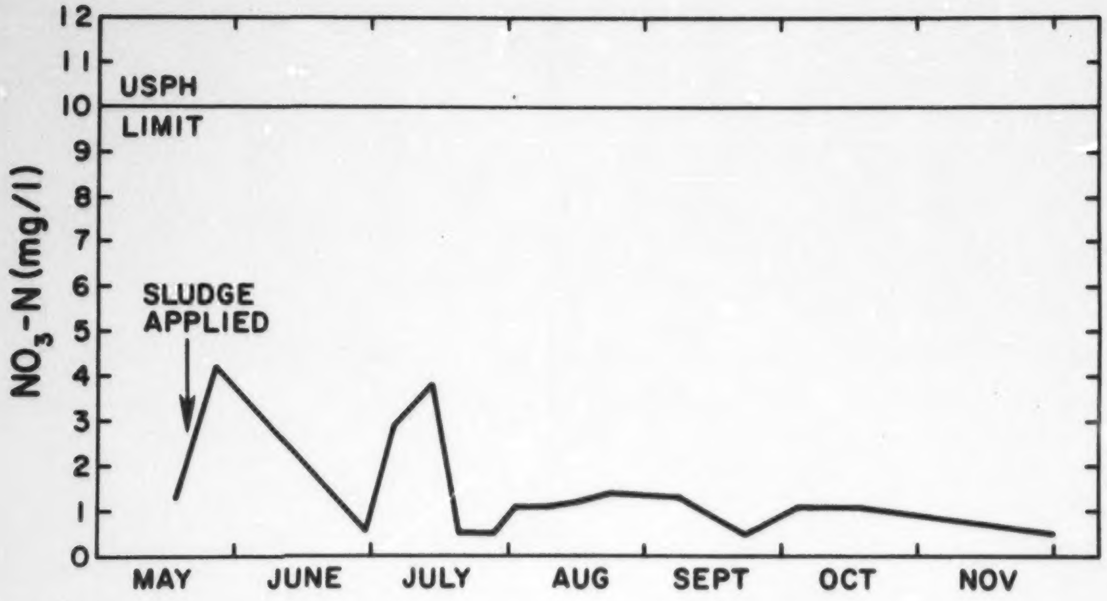

Figure 12. Concentration of NO_3-N in Lake No. 1.

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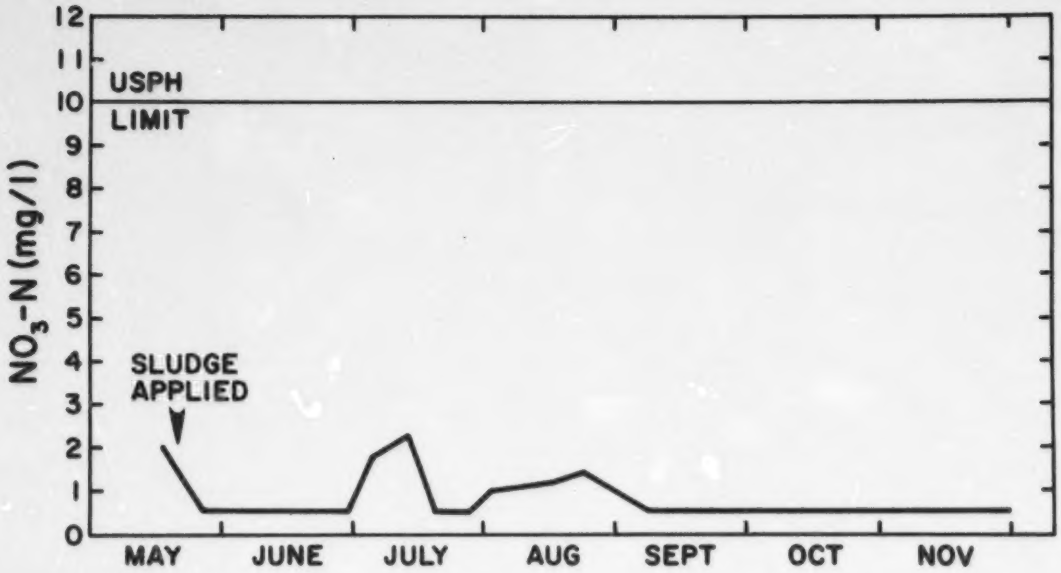

Figure 13. Concentration of NO_3-N in Lake No. 2.

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TABLE 32. LAKE WATER ANALYSES FOR COPPER, ZINC, AND CADMIUM FOR 1977 AT THE VENANGO COUNTY DEMONSTRATION PROJECT

Lake No. and Month	Cu	Zn	Cd
	mg/1		
Lake 1			
June	0.01	1.35	0.001
July	0.01	0.64	<0.001
Aug	0.01	0.33	<0.001
Sept	0.01	0.30	0.001
Oct	<0.01	0.27	0.001
Nov	0.01	0.27	0.001
Lake 2			
June	0.01	0.67	<0.001
July	0.01	0.08	<0.001
Aug	0.01	0.05	<0.001
Sept	0.01	<0.01	0.001
Oct	<0.01	<0.01	<0.001
Nov	0.01	<0.01	<0.001

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TABLE 33. LAKE WATER ANALYSES FOR COPPER, ZINC, AND CADMIUM FOR 1978 AT THE VENANGO COUNTY DEMONSTRATION PROJECT

Lake No. and Month	Cu	Zn	Cd
	- - - - - - - - -	mg/l	- - - - - - - - -
Lake 1			
April	0.01	0.17	0.001
May	0.02	1.50	0.001
June	<0.01	0.29	0.001
July	0.01	0.09	0.001
Aug	0.01	0.40	0.002
Sept	0.02	0.82	0.001
Oct	<0.01	0.33	<0.001
Nov	<0.01	0.37	0.001
Dec	<0.01	0.03	<0.001
Lake 2			
April	0.01	0.86	<0.001
May	0.01	0.02	<0.001
June	<0.01	0.02	<0.001
July	0.01	0.28	0.001
Aug	0.02	0.47	<0.001
Sept	0.01	1.05	<0.001
Oct	0.01	0.62	<0.001
Nov	<0.01	<0.01	<0.001
Dec	<0.01	<0.01	0.001

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TABLE 34. LAKE WATER ANALYSES FOR COPPER, ZINC, AND CADMIUM AT THE VENANGO COUNTY DEMONSTRATION PROJECT FOR 1979

Lake No. and Month	Cu	Zn	Cd
	mg/l		
Lake 1			
March	<0.01	0.12	0.001
April	<0.01	0.15	<0.001
May	<0.01	0.14	<0.001
June	<0.01	0.17	<0.001
July	<0.01	0.24	0.001
Aug	0.05	0.36	<0.001
Sept	0.02	0.95	<0.001
Oct	0.01	0.01	<0.001
Lake 2			
March	<0.01	0.02	<0.001
April	<0.01	0.21	<0.001
May	0.01	0.01	<0.001
June	<0.01	0.01	<0.001
July	<0.01	0.02	<0.001
Aug	0.01	1.42	<0.001
Sept	<0.01	0.01	<0.001
Oct	0.01	0.30	<0.001

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SECTION 5

LACKAWANNA COUNTY DEMONSTRATION

SITE SELECTION

During June, 1977 a site was located in the anthracite coal region of Northeastern Pennsylvania (Figure 1). A meeting of representatives from the cooperating agencies was held on July 14, 1977 to determine the feasiblity of the site. The site is located in the City of Scranton, Lackawanna County (Figure 14), and is owned by the Pennsylvania Department of Transportation. The site is typical of abandoned refuse banks that had not been leveled and was devoid of vegetation.

In March, 1978 a legal agreement between the Pennsylvania Department of Transportation and Agricultural Stabilization and Conservation Service, USDA was signed for the use of a 4 hectare area for the demonstration project. Representatives from the cooperating agencies met at the site for groundbreaking ceremonies on April 20, 1978.

DEMONSTRATION PROJECT DESIGN

Sludge for the project was obtained from the Scranton Wastewater Treatment plant. The plant produces a dewatered sludge. To maximize the value of the demonstration project the sludge was applied to the site at two application rates.

Pre-Treatment Soil Sampling

On May 9, 1978, twelve soil pits were excavated with a backhoe to a depth of 90 cm. Each pit was used for the collection of soil samples and for the installation of suction lysimeters for percolate water sample collection. Four soil pits were excavated in each sludge treatment and in an adjacent area for control data. Soil samples were collected at the 0-15, 15-30, 30-60 and 60-90 cm depth for chemical analyses. These samples were analyzed in the same manner as the samples from the Venango County demonstration. Results of these analyses are given in Appendix Tables A-29 to A-31.

Monitoring Instrumentation

Two suction lysimeters were installed at the 90-cm soil depth for the collection of percolate water samples. Groundwater well sites were selected

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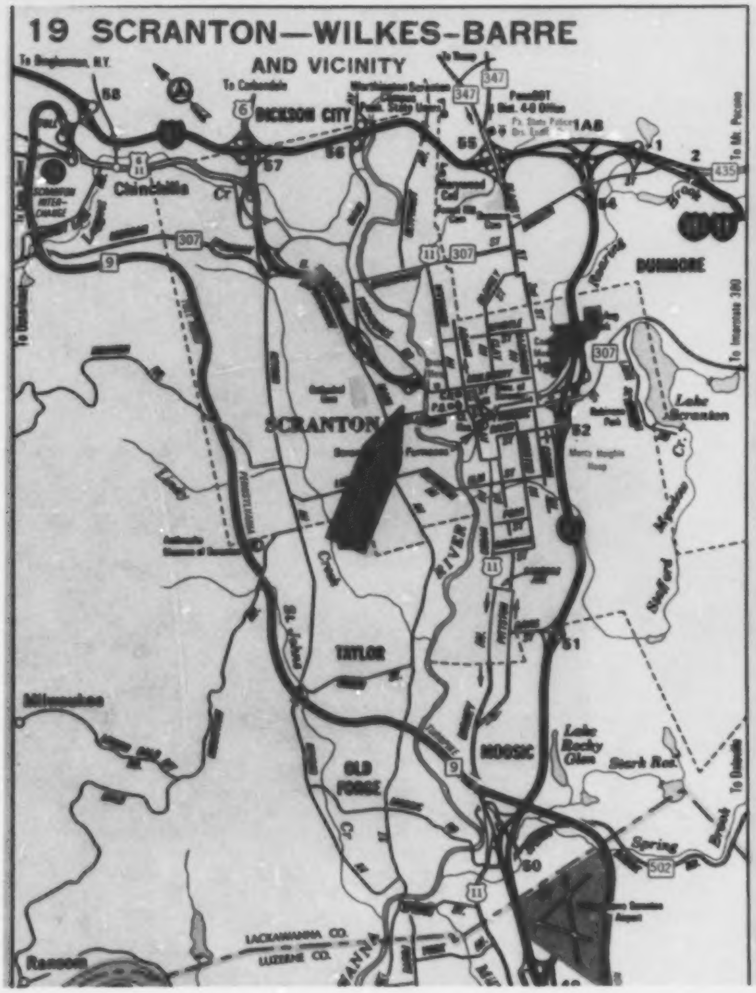
19 SCRANTON—WILKES-BARRE
AND VICINITY
To Binghamton, N.Y.
To Carbondale
DICKSON CITY
Chinchilla
To Mt. Pocono
DUNMORE
To Interstate 380
Lake Scranton
SCRANTON
RIVER
TAYLOR
MOOSIC
Lake Rocky Glen
Stark Res.
To Daleville
OLD FORGE
Milwaukee
Spring
LACKAWANNA CO.
LUZERNE CO.
Ransom
307
347
435
502
6
9
11

Figure 14. Location of the demonstration project in the City of Scranton, Lackawanna County.

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by geologists of the Bureau of Solid Waste Management, Pennsylvania Department of Environmental Resources. Three 15-cm diameter groundwater wells were drilled on June 6, 1978 to monitor the effects of the sludge applications on groundwater quality. The depth of each well and the depth to the water level at the time of drilling was as follows:

Well No.	Total Depth m	Depth to Water Level m
1 (Control)	51.5	35.6
2	40.2	22.2
3	37.5	22.9

Samples were collected and analyzed in a similar manner as the Venango County Demonstration project.

6-1/2"

SLUDGE ANALYSIS

The site is located approximately 6 km from the Scranton Wastewater Treatment Plant. The plant currently treats approximately 95,000 cubic meters of wastewater per day. Treatment consists of primary settling, activated sludge, and final settling. Solids collected in the primary and secondary settling tanks, referred to as sludge, are thickened by floatation, treated with lime and ferric chloride and then vacuum-filtered.

Because of the daily variation in concentrations of constituents in the sludge, samples of the sludge were collected as it was applied on the demonstration plots. Results of the sludge analyses (Table 35) were used to determine the actual application rates and to calculate the amounts of selected nutrients and trace metals applied in the two application rates (Table 36). A comparison of the sludge application rates with the EPA and PDER recommendations for maximum trace metal loadings on the land is given in Table 37.

This comparison indicates that the recommended EPA and PDER limits were essentially met even with the high sludge application rate of 108 mt per ha. It should also be noted that the 108 mt/ha sludge application rate also meets the limits established for the use of sludge for reclamation for farming purposes except for copper. The PDER guidelines recommend a maximum copper loading rate of 67 kg/ha, whereas the actual sludge application was 92 kg/ha.

The commercial fertilizer equivalents of the two sludge application rates are given in Table 38. The high sludge application rate would be equivalent to applying 11 mt per ha of a 15-9-2 commercial fertilizer.

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TABLE 35. CHEMICAL ANALYSIS OF DEWATERED SLUDGE APPLIED ON THE LACKAWANNA COUNTY DEMONSTRATION PROJECT

Constituent	Mean	Range	
		Low	High
pH	8.9	7.9	11.8
	- - - - - ppm on dry weight basis - - - - -		
Total P	4190	3708	4863
NO_3-N	137	41	212
NH_4-N	3271	135	5261
Org-N	12215	4613	17504
Ca	79257	48836	126216
Mg	4724	3168	6969
Na	714	493	886
K	1292	1029	1632
Al	6550	5252	8897
Mn	1427	965	2032
Fe	31903	17371	46114
Co	8	2	16
Zn	776	616	1127
Cu	865	663	1098
Pb	613	494	766
Cr	202	151	241
Ni	57	42	67
Cd	16.4	12.8	20.7
Hg	1.3	0.8	1.9
	- - - - - - - - - - % - - - - - - - - - -		
Total P	0.42	0.37	0.49
Total N	1.56	0.96	1.97
Solids	28.83	24.74	35.17

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TABLE 36. AMOUNTS OF PLANT NUTRIENTS AND TRACE METALS APPLIED AT THE TWO SLUDGE APPLICATION RATES ON THE LACKAWANNA COUNTY DEMONSTRATION PROJECT

Constituent	Sludge Application Rate in Dry Tons Per Hectare	
	80	108
	kg/ha	
Total N	1241	1691
P	334	456
K	103	141
Cu	67	92
Zn	64	86
Cr	16	21
Pb	49	67
Ni	4.4	5.9
Co	0.8	1.1
Cd	1.2	1.7
Hg	0.12	0.17

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TABLE 37. COMPARISON OF TRACE METAL LOADINGS AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT WITH EPA AND PDER RECOMMENDATIONS

Constituent	Sludge Application Rate (mt/ha) 80	108	Recommendations EPA (CEC 5-15)*	PDER
	------------- kg/ha	-------------	-------------	-------------
Cd	1.2	1.7	11	3
Cu	67	92	280	112
Cr	16	21	NR†	112
Pb	49	67	1120	112
Hg	0.12	0.17	NR†	0.6
Ni	4.4	5.9	280	22
Zn	64	86	560	224

* Average CEC of site ranged from 7.8 to 10.4 meq/100g.

† No recommendation given by EPA.

TABLE 38. COMMERCIAL FERTILIZER EQUIVALENTS OF THE SLUDGE APPLICATION RATES IN LACKAWANNA COUNTY

Sludge Application Rate	Fertilizer Equivalent (Fertilizer Formula) Amount	N	P_2O_5	K_2O
mt/ha	kg/ha	kg/ha (%)	kg/ha (%)	kg/ha (%)
80	11,200	1241 (11)	764 (7)	123 (1)
108	11,200	1691 (15)	1044 (9)	169 (2)

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SITE PREPARATION

Leveling

The demonstration area was leveled according to a conservation plan developed by the Soil Conservation Service, United States Department of Agriculture. On March 20, 1978 the leveling operation began and was completed by May 12, 1978.

Liming

Pre-treatment surface refuse samples were analyzed for pH and buffer pH to determine the liming requirements. Results indicated that the average refuse pH was 3.6. Eleven metric tons of agricultural lime per hectare were applied on May 30, 1978 to adjust the refuse pH to 7.0.

SLUDGE APPLICATION

During the period of May 30, 1978 to June 2, 1978, the dewatered sludge was transported by 20 ton capacity trucks from the Scranton Waste Treatment Plant to the site. A total of 847 metric tons of sludge, at 28.8 percent solids, was delivered to the site. The sludge was loaded with a front-end loader into rear-delivery manure spreaders and spread on the site; this was completed on June 2, 1978. Immediately after the spreading, the area was disked to incorporate the sludge into the surface 10 cm of refuse material; this was also completed by June 2, 1978.

VEGETATION SEEDING AND MULCHING

After the incorporation of the sludge, the area was broadcast seeded with a tractor-mounted box seeder on June 6, 1978. The seed mixture used was:

	kg per hectare
Kentucky 31 tall fescue	28
Pennlate orchardgrass	28
Penngift crownvetch	17
Birdsfoot trefoil	17
Total	90

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On June 12, 1978, Penn Line Service, Inc. mulched the entire demonstration area with straw and hay at the rate of 3.3 mt per hectare.

DIVERSION DITCHES AND BERM

The diversion ditches were limed at the same rate as the demonstration plot, 11 mt/ha. Commercial fertilizer at a rate of 1.1 mt/ha of a 10-20-20 fertilizer was spread on the diversion ditches and they were subsequently seeded with the same seeding mixture as the demonstration plots. The sloped berms surrounding the sludge plots received the same amounts of lime, commercial fertilizer, and seed as the diversion ditches, however they were applied by hydroseeding. All work on the site was completed by June 12, 1978.

RESULTS

Vegetation Growth Responses

8-1/2"

Vegetation growth responses were evaluated at the end of each growing season. Measurements of vegetation heights were taken at 10 locations along each of two transect lines in each sludge treatment plot. Sampling points were spaced evenly along each transect line. The results of these measurements are given in Table 39. There was a complete vegetative cover on the sludge-treated areas by August 1978, two months after the sludge application. Average growth the first year ranged from 22 to 86 cm with the greatest height being produced with the higher sludge application rate (108 mt/ha). In 1979 the average height of the vegetation was almost double that of the first year and there was no significant difference between the sludge application rates.

To determine dry matter production, twenty, 0.1 m^2 samples of the vegetative cover were collected in each of the sludge treatment plots. Four 0.1 m^2 samples of the vegetation were clipped along five transect lines in each area. The results are given in Table 39. Dry matter production the first year ranged from 1505 to 18950 kg/ha with the highest average dry-matter production found in the 80 mt/ha sludge treatment plot. In 1979, the average dry matter production was more than double that of the first year. There was no significant difference in dry matter production between the two sludge application rates.

Individual samples of each of the two grass and two legume species were collected from each sludge-treated area for foliar analyses. Foliar samples were prepared for analyses in the same manner as samples collected from the Venango County demonstration site.

At the end of each growing season individual samples of the two grass and two legume species were collected from each sludge-treated plot for foliar analyses. In addition, samples were also collected of volunteer panic grass (*Panicum dichotomiflorum* Michx.) that invaded the sludge-treated plots from the surrounding untreated area. This provided an opportunity to

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TABLE 39. VEGETATION HEIGHT GROWTH AND DRY MATTER PRODUCTION AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT DURING 1978 AND 1979

Sludge Application	Height 1978	Height 1979
mt/ha	cm	cm
80	35	82
108	47	81

Sludge Application	Dry Matter Production 1978	Dry Matter Production 1979
mt/ha	kg/ha	kg/ha
80	3988	8179
108	3321	7267

evaluate the effect of the sludge applications on foliar elemental concentrations for a single common species. Results of these analyses are given in Tables 40 to 42. There was no significant difference in foliar concentrations between the two sludge application rates. Some species differences were noted in that of the seeded species, tall fescue had the highest foliar concentrations of N, K, Ca, Mg, Fe, and Al (Table 40).

Results of the foliar analyses for concentrations of trace metals are given in Tables 41 and 42. In general, there is little difference between foliar concentrations for the two sludge application rates. The legume species had slightly higher concentrations than the grass species. Results of the panic grass foliar analyses indicate that there was little difference in trace metal concentrations on the sludge-treated plots in comparison to the surrounding untreated area. In fact, trace metal concentrations of Zn, Cr, Pb, and Ni were higher in the foliage of the panic grass on the untreated area than on sludge-treated areas. In general, foliar concentrations decreased during the second growing season (1979). It should be noted that all trace metal concentrations are well below the suggested tolerance levels and no phytotoxicity symptoms were observed.

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TABLE 40. MEAN CONCENTRATIONS OF SELECTED CONSTITUENTS IN VEGETATION FOLIAR SAMPLES COLLECTED AT THE END OF THE 1978 GROWING SEASON FROM THE LACKAWANNA COUNTY DEMONSTRATION PROJECT

Species	Sludge Application	N	P	K	Ca	Mg	Mn	Fe	B	Al
	mt/ha	- - - -	- - - -	%	- - - -	- - - -	- - -	μg/g	- - -	- - -
Birdsfoot Trefoil	80	2.67	0.15	1.70	1.59	0.32	254	310	35.7	182
	108	3.08	0.17	1.60	1.60	0.30	369	128	38.6	62
Crownvetch	80	2.99	0.18	1.54	1.66	0.27	148	112	36.9	57
	108	3.09	0.20	1.63	1.86	0.25	131	115	42.3	57
Tall Fescue	80	3.10	0.17	1.67	3.00	0.46	82	306	40.5	143
	108	3.25	0.17	1.83	2.38	0.42	135	387	41.2	224
Orchard-grass	80	3.15	0.18	1.66	2.01	0.22	81	119	39.0	59
	108	2.69	0.16	1.70	1.68	0.24	90	124	25.6	60
Panic Grass	0	1.01	0.27	1.20	0.14	0.32	202	244	5.5	121
	80	2.16	0.30	1.14	0.45	0.67	92	195	6.1	85
	108	1.68	0.35	1.03	0.45	0.59	262	152	7.7	52

Percolate Water Quality

Results of the analyses for selected chemical constituents for percolate water collected at the 90-cm depth in 1978 and 1979 for both of the sludge treated areas as well as the control area are given in Tables 43 to 46 and in Appendix Tables A-32 and A-33. Average concentrations of nitrate-nitrogen in all areas never approached the potable water standard of 10 mg/l following sludge application, with the highest value recorded for NO_3-N being 1.5 mg/l. Orthophosphate-P concentrations were only slightly increased by the sludge applications. Results also indicate that the applications of lime and sludge had little effect on the pH of soil percolate water at the 90 cm depth.

Concentrations of trace metals in the percolate on both sludge-treated plots were extremely low (Tables 45 and 46). There appears to be no significant increase in the concentrations of trace metals as a result of sludge applications to the anthracite refuse. It should also be noted that trace metal concentrations in soil percolate water decreased in the second year (1979) after sludge application. Concentrations of all trace metals in soil percolate water were below the U.S. Public Health Service limits for potable water.

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TABLE 41. MEAN CONCENTRATIONS OF TRACE METALS IN VEGETATION FOLIAR SAMPLES COLLECTED AT THE END OF THE 1978 GROWING SEASON FROM THE LACKAWANNA COUNTY DEMONSTRATION PROJECT

Sludge Application	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha	μg/g						
			Birdsfoot Trefoil				
80	4.0	65.6	0.8	15.2	4.2	0.11	8.1
108	13.4	79.6	1.1	15.7	3.2	0.18	9.0
			Crownvetch				
80	19.3	130.0	0.8	16.0	2.9	0.52	7.4
108	17.9	128.2	0.8	13.5	2.3	0.78	7.7
			Tall Fescue				
80	11.5	46.3	1.0	5.7	0.9	0.36	4.2
108	13.1	47.0	1.1	5.8	1.0	0.39	2.9
			Orchardgrass				
80	13.7	53.9	0.5	5.2	2.0	0.22	5.2
108	13.7	55.1	0.5	4.3	2.3	0.31	5.1
			Panic Grass				
0	9.6	41.7	0.9	3.7	0.8	0.11	4.3
80	15.3	40.4	0.5	2.3	1.3	0.15	2.6
108	10.7	59.4	0.7	3.0	1.4	0.11	3.3
Suggested Tolerance Levels [*, †]	150	300	2	10	5	3	50

[*] Melsted (1973).

[†] Council for Agricultural Science and Technology (1976)

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TABLE 42. MEAN CONCENTRATIONS OF TRACE METALS IN VEGETATION FOLIAR SAMPLES COLLECTED AT THE END OF THE 1979 GROWING SEASON FROM THE LACKAWANNA COUNTY DEMONSTRATION PROJECT

Sludge Application	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha				µg/g			
				Birdsfoot Trefoil			
80	11.8	49.3	0.6	5.7	0.6	0.04	4.7
108	11.6	50.1	0.3	6.0	0.7	0.05	4.8
				Crownvetch			
80	11.0	59.4	0.5	3.9	1.3	0.08	2.2
108	11.3	54.2	0.5	3.7	1.0	0.09	2.4
				Tall Fescue			
80	7.1	24.9	0.3	0.8	0.8	0.07	1.8
108	11.0	31.1	0.5	1.4	0.5	0.09	2.1
				Orchardgrass			
80	12.5	40.5	0.3	3.0	1.2	0.09	2.8
108	12.1	35.3	0.3	2.8	0.5	0.08	1.8
				Panic Grass			
0	11.3	41.8	0.4	5.0	0.2	0.07	2.7
80	16.3	34.7	0.2	1.0	0.3	0.05	1.9
108	20.5	44.3	0.3	2.3	0.3	0.06	1.8
Suggested Tolerance Levels [*], [†]	150	300	2	10	5	3	50

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[*] Melsted (1973).

[†] Council for Agricultrual Science and Technology (1976)

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TABLE 43. SOIL PERCOLATE ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT DURING 1978

Sludge Application	Month	Ortho P	NO_3-N	NH_4-N	Org-N	pH
mt/ha		- - - - - -	- - - -	mg/l	- - - -	- - - -
0	May	0.011*	0.5	0.93	0.25	4.8
	June	0.021	0.5	0.64	0.03	4.4
	July	0.020	0.5	1.01	0.19	4.5
	Aug	0.028	0.6	1.41	0.20	4.0
	Sept	0.017	0.5	0.34	0.41	3.9
	Oct	0.015	0.5	0.30	0.27	4.1
	Nov	0.017	0.5	0.30	0.19	4.1
	Dec	0.021	0.5	0.32	0.09	4.0
80	May	0.015	0.5	0.68	0.14	4.5
	June	0.031	0.5	1.87	0.16	4.1
	July	0.038	0.8	1.58	0.56	4.2
	Aug	0.030	0.9	2.18	0.53	3.8
	Sept	0.034	1.4	0.42	0.50	3.6
	Oct	0.027	0.7	0.28	0.33	3.9
	Nov	0.053	0.8	0.30	0.37	4.1
	Dec	0.032	0.6	0.30	0.20	3.9
108	May	0.015	0.5	0.81	0.32	4.3
	June	0.033	0.5	0.68	0.16	4.2
	July	0.032	0.5	1.55	0.28	4.2
	Aug	0.042	0.5	2.21	1.37	4.0
	Sept	0.046	0.5	1.39	0.59	3.6
	Oct	0.033	0.7	0.35	0.14	3.9
	Nov	0.044	0.5	0.23	0.10	4.0
	Dec	0.028	0.5	0.16	0.09	4.0

* Values represent mean of all samples collected from the sludge treatment area on that date.

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TABLE 44. SOIL PERCOLATE ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT DURING 1979

Sludge Application	Month	Ortho P	NO_3-N	NH_4-N	Org-N	pH
mt/ha		- - - - - - - - - -	- - - -	mg/l	- - - - - - - - - -	
0	March	0.019	<0.5	0.14	0.10	3.8
	April	0.026	<0.5	0.14	0.09	4.0
	May	0.025	0.7	0.72	0.18	4.2
	June	0.023	<0.5	0.31	0.08	4.0
	July	0.033	1.0	0.60	0.18	4.0
	Aug	<0.001	0.8	1.24	0.68	4.5
	Sept	0.012	<0.5	0.23	0.11	3.7
	Oct	0.021	<0.5	0.18	0.19	3.9
80	March	0.023	0.9	0.20	0.33	4.5
	April	0.018	0.6	0.20	0.14	4.1
	May	0.040	1.4	0.92	0.17	4.8
	June	0.037	0.9	0.36	0.23	4.4
	July	0.031	1.5	1.02	0.42	4.7
	Aug	0.012	<0.5	0.54	0.27	4.4
	Sept	0.019	0.7	0.31	0.24	4.2
	Oct	0.022	0.6	0.32	0.27	4.7
108	March	0.023	<0.5	0.16	0.10	3.8
	April	0.015	<0.5	0.13	0.69	4.1
	May	0.023	0.6	0.92	0.13	4.1
	June	0.038	<0.5	0.42	0.17	4.1
	July	0.032	<0.5	0.70	0.20	3.9
	Aug	0.016	0.6	0.64	0.15	4.0
	Sept	0.012	<0.5	0.22	0.16	4.1
	Oct	0.023	0.6	0.25	0.29	4.2

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TABLE 45. SOIL PERCOLATE ANALYSES FOR TRACE METALS AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT DURING 1978

Sludge Application	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha					mg/l			
0	May	0.07*	3.10	0.02	0.32	0.34	0.011	0.59
	June	0.08	2.99	0.01	0.50	0.32	0.018	0.51
	July	0.10	2.90	0.02	0.10	0.33	0.012	0.58
	Aug	0.13	3.06	0.03	0.12	0.39	0.012	0.53
	Sept	0.09	2.77	0.02	0.10	0.41	0.011	0.52
	Oct	0.08	2.16	<0.01	0.07	0.28	0.009	0.57
	Nov	0.09	2.26	<0.01	0.05	0.26	0.009	0.56
	Dec	0.07	2.26	0.01	0.06	0.29	0.008	0.55
80	May†	0.05	0.49	0.01	0.29	<0.01	0.002	0.05
	June	0.05	0.77	0.02	0.28	0.03	0.002	0.08
	July	0.06	0.52	0.01	0.05	0.03	0.001	0.08
	Aug	0.08	0.55	0.04	0.07	0.05	0.002	0.06
	Sept	0.09	0.60	0.01	0.09	0.09	0.001	0.06
	Oct	0.09	0.84	<0.01	0.03	0.04	0.002	0.13
	Nov	0.09	0.47	<0.01	0.04	0.04	0.003	0.15
	Dec	0.08	0.44	<0.01	0.02	0.03	0.002	0.13
108	May	0.03	0.37	0.01	0.26	0.03	0.002	0.08
	June	0.05	0.86	0.02	0.36	0.06	0.005	0.05
	July	0.06	0.69	0.02	0.09	0.07	0.003	0.13
	Aug	0.07	0.88	0.04	0.08	0.12	0.003	0.14
	Sept.	0.08	1.43	0.01	0.10	0.19	0.004	0.15
	Oct	0.06	0.97	<0.01	0.03	0.06	0.003	0.18
	Nov	0.05	0.83	<0.01	0.03	0.08	0.003	0.18
	Dec	0.04	0.83	<0.01	0.03	0.11	0.003	0.17
USPHS Drinking Water Standards		1.0	5.0	0.05	0.05	5.0	0.01	2.0

[*] Values represent the mean of all samples collected from the plot for the month.

[†] May samples represent pre-treatment conditions.

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TABLE 46. SOIL PERCOLATE ANALYSES FOR TRACE METALS AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT DURING 1979

Sludge Application	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha		- - - - -	- - - - -	- - - -	mg/l	- - - -	- - - - -	- - - - -
0	March	0.06	1.32	0.01	0.06	0.27	0.003	0.39
	April	0.10	0.91	0.01	0.05	0.15	0.002	0.31
	May	0.05	1.40	0.02	0.08	0.18	0.002	0.37
	June	0.05	1.15	0.03	0.08	0.20	0.002	0.32
	July	0.07	1.51	0.02	0.09	0.19	0.002	0.39
	Aug	0.07	0.62	<0.01	0.02	0.03	0.001	0.10
	Sept	0.09	0.52	<0.01	0.07	0.03	0.001	0.10
	Oct	0.05	0.45	0.01	0.03	0.03	0.001	0.06
80	March	0.03	0.23	<0.01	<0.01	0.04	0.001	0.04
	April	0.08	0.26	0.01	0.01	0.01	0.001	0.06
	May	0.13	0.29	<0.01	0.01	0.02	0.001	0.07
	June	0.04	0.20	<0.01	0.03	0.03	0.001	0.07
	July	0.09	0.28	0.02	0.03	0.07	0.001	0.07
	Aug	0.04	0.99	0.01	0.03	0.05	0.001	0.10
	Sept	0.04	0.45	0.01	0.03	0.07	0.001	0.12
	Oct	0.04	0.40	0.01	0.07	0.03	0.001	0.05
108	March	0.02	0.34	<0.01	0.04	0.05	0.001	0.05
	April	0.09	0.45	<0.01	0.04	0.05	0.001	0.12
	May	0.07	0.44	0.01	0.05	0.05	0.001	0.10
	June	0.03	0.29	0.01	0.04	0.07	0.001	0.07
	July	0.06	0.32	0.01	0.06	0.06	0.001	0.06
	Aug	0.03	0.99	0.01	0.07	0.10	0.002	0.23
	Sept	0.03	1.00	<0.01	0.06	0.10	0.002	0.22
	Oct	0.05	0.96	0.01	0.06	0.07	0.003	0.17
USPHS Drinking Water Standards		1.0	5.0	0.05	0.05	5.0	0.01	2.0

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Separate samples of percolate water were collected from the lysimeters for total and fecal coliform analyses. No total or fecal coliform colonies (per 100 ml aliquots) were observed for any sample.

Groundwater Quality

Results of the analyses of groundwater well samples are given in Tables 47 to 50 and in Appendix Tables A-34 and A-35. Well 1 was drilled as a control, outside the area of influence of the sludge applications. The values presented for Well 1 reflect the general groundwater quality for the disturbed site. Groundwater flow under the sludge-treated areas is toward Wells 2 and 3, therefore reflecting the effects of the sludge applications on groundwater quality. Results indicate that the sludge applications had little or no effect on the groundwater quality with only slight increases in the concentrations of orthophosphate-P and zinc. The concentration of zinc in samples from Well 2 increased from 0.53 to 1.09 mg/l and in Well 3 from 0.75 to 0.89 mg/l. However, the highest zinc concentration recorded (1.09 mg/l) is still well below the drinking water standard for zinc of 5.00 mg/l. In fact, all concentrations of trace metals in groundwater were below the U.S. Public Health Service limits for potable water. Samples of the groundwater were collected for total fecal coliform analyses. There were no fecal coliform colonies observed for any sample to date.

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TABLE 47. GROUNDWATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT DURING 1978

Well No.	Month	Ortho P	NO_3-N	NH_4-N	Org-N	pH
		mg/l				
Well 1 (Control)	July	0.025	<0.5	1.45	0.75	5.5
	Aug	0.021	<0.5	1.02	--	5.9
	Sept	0.005	<0.5	1.65	0.31	7.5
Well 2 (Treated)	July	0.064	<0.5	0.88	0.37	6.6
	Aug	0.092	<0.5	0.87	0.24	6.8
	Sept	0.013	<0.5	0.88	0.24	7.1
	Oct	0.009	<0.5	1.10	0.06	6.9
	Nov	0.024	<0.5	0.92	0.28	6.4
	Dec	0.119	<0.5	1.10	--	7.0
Well 3 (Treated)	July	0.008	<0.5	0.67	0.20	6.1
	Aug	0.004	<0.5	0.68	0.36	6.3
	Sept	0.005	<0.5	0.81	0.45	6.3
	Oct	--	--	--	--	--
	Nov	0.009	<0.5	0.98	0.22	6.7
	Dec	0.005	<0.5	0.92	0.26	6.1

TABLE 48. GROUNDWATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT DURING 1979

Well No.	Month	Ortho P	NO_3-N	NH_4-N	Org-N	pH
		mg/l				
Well 2 (Treated)	March	0.056	1.0	0.98	0.52	6.9
	April	0.003	<0.5	0.86	0.26	6.4
	May	0.003	<0.5	0.86	0.40	6.7
	June	<0.001	<0.5	0.94	0.34	6.8
	July	<0.001	<0.5	0.94	0.32	6.9
	Aug	<0.001	<0.5	0.98	0.48	7.1
	Sept	<0.001	<0.5	0.80	0.40	6.7
	Oct	0.007	<0.5	1.05	0.41	6.5

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TABLE 49. GROUNDWATER ANALYSES FOR TRACE METALS AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT DURING 1978

Well No.	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
		mg/1						
Well 1 (Control)	July	0.14	3.45	0.01	0.18	0.28	0.002	0.38
	Aug	0.15	1.03	0.05	0.20	0.22	<0.001	0.19
	Sept	0.37	0.59	0.01	0.16	0.05	0.003	0.11
Well 2 (Treated)	July	0.12	0.53	0.01	0.07	0.03	0.001	0.01
	Aug	0.11	0.43	0.04	0.07	0.03	<0.001	<0.01
	Sept	0.07	1.09	0.01	0.07	0.03	<0.001	<0.01
	Oct	0.41	0.72	<0.01	0.10	0.01	<0.001	0.01
	Nov	0.06	0.21	<0.01	0.10	0.01	0.001	0.01
	Dec	0.02	0.10	0.01	0.04	0.01	<0.001	0.01
Well 3 (Treated)	July	0.14	0.75	0.01	0.05	0.03	0.001	0.02
	Aug	0.10	0.73	0.04	0.10	0.07	0.002	0.01
	Sept	0.11	0.89	0.01	0.05	0.04	<0.001	<0.01
	Oct	--	--	--	--	--	--	--
	Nov	0.06	0.35	<0.01	0.04	0.02	<0.001	0.03
	Dec	0.05	0.45	<0.01	0.02	0.02	<0.001	0.05
USPHS Drinking Water Standards		1.0	5.0	0.05	0.05	5.0	0.01	2.0

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TABLE 50. GROUNDWATER ANALYSES FOR TRACE METALS AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT DURING 1979

Well No.	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
		- - - -	- - - -	- - - -	mg/l	- - - -	- - - -	- - - -
Well 2 (Treated)	March	0.08	0.28	0.01	0.06	0.01	<0.001	<0.01
	April	0.06	0.23	0.01	0.01	<0.01	<0.001	<0.01
	May	0.09	0.17	0.01	0.07	<0.01	<0.001	<0.01
	June	0.07	0.41	0.01	0.03	<0.01	0.001	0.04
	July	0.17	0.70	0.01	0.06	0.03	0.001	0.04
	Aug	0.13	0.84	<0.01	<0.01	0.01	0.001	0.05
	Sept	0.11	1.35	<0.01	0.05	0.01	0.001	0.05
	Oct	0.08	0.50	0.01	0.02	<0.01	0.001	0.02
USPHS Drinking Water Standards		1.0	5.0	0.05	0.05	5.0	0.01	2.0

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SECTION 6

WESTMORELAND COUNTY DEMONSTRATION

SITE SELECTION

During the spring of 1979, a site was located in the bituminous coal region of Southwestern Pennsylvania (Figure 1). The site is located in Derry Township, Westmoreland County (Figure 15), and is owned by Victor Smith. The area had been mined approximately 10 years ago and is typical of bituminous spoil banks that had been recontoured without topsoil replacement. Four hectares of the approximate 6 hectare area was selected for sludge application.

DEMONSTRATION PROJECT DESIGN

Sludge for the project was obtained from the City of Philadelphia Water Pollution Control Plant. The plant produces a dewatered centrifuged sludge that is composed with woodchips. To maximize the value of the demonstration project, the sludge was applied in the fall rather than the spring as with the other two demonstration sites. This would allow the evaluation of a fall seeding on the establishment of a vegetative cover and the efficacy of that cover to control the environmental effects of the sludge application.

Pre-treatment Soil Sampling

On August 8, 1979, seven soil pits were excavated with a backhoe to a depth of 90 cm. Each pit was used for the collection of soil samples and for the installation of suction lysimeters for percolate water collection. Five soil pits were excavated in the sludge treatment area and two pits were excavated in the adjacent area for control data. Soil samples were collected at the 0-15, 15-30, 30-60, and 60-90 cm depth for chemical analyses. These samples were analyzed in the same manner as the samples from the other two demonstration projects.

Monitoring Instrumentation

Two suction lysimeters were installed at the 90 cm depth in each of the seven soil pits for the collection of soil percolate water samples. Groundwater well sites were selected by geologists of the Bureau of Solid Waste Management, Pennsylvania Department of Environmental Resources. Two 15 cm diameter groundwater wells were drilled on September 18, 1979 to monitor the effects of the sludge application on groundwater quality. The depth of each

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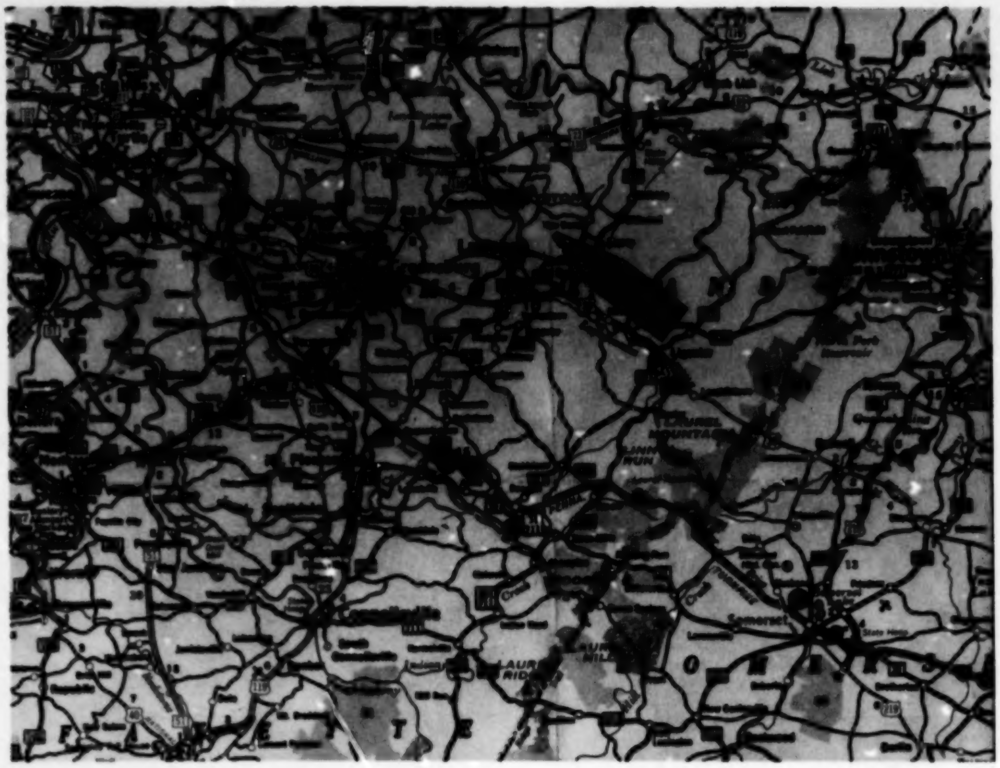

Figure 15. Location of the demonstration project in Westmoreland County.

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well and the depth to the water level at the time of drilling was as follows:

Well No.	Total Depth m	Depth to Water Level m
1	11.6	1.7
2	11.6	Artesian

Samples were collected and analyzed in a similar manner as the other demonstration projects.

SLUDGE ANALYSIS

The site is located approximately 450 kilometers from the Philadelphia Water Pollution Control Plant.

Sludge produced from secondary treatment is digested in eight anaerobic digestors prior to centrifugation. Two new Sharples-Stokes centrifuges then produce a sludge cake with a solids content of 20 to 25 percent. Each centrifuge is capable of processing 50 metric tons per day. The sludge is finally composted with wood chips and stored. Prior to transportation the composted sludge is mixed with centrifuged sludge cake. The mixing ratio is one part of centrifuged sludge to one part of composted sludge. The rationale for this mix is to increase the nutrient value of the sludge. The total nitrogen content of the composted sludge is only approximately 0.6 percent whereas the nitrogen content of the centrifuged sludge cake is approximately 2.0 percent.

Because of the daily variation in concentrations of constituents in the sludge, samples of the sludge were collected as it was applied on the demonstration area. Results of the sludge analyses (Table 51) were used to determine the actual application rate and to calculate the amounts of selected nutrients and trace metals applied (Table 52). A comparison of the sludge application rates with the EPA and PDER recommendations for maximum trace metal loadings on the land is given in Table 53. This comparison indicates that the recommended limits were essentially met with the sludge application rate of 134 mt/ha. It should be noted that the sludge application of 134 mt/ha is well below the limits recommended by the EPA and that with the exception of zinc meets all PDER guidelines. The recommended maximum loading rate, established by the PDER guidelines, for zinc is 224 kg/ha, whereas the actual sludge application was 245 kg/ha.

The results of the sludge analyses indicated that it supplied 968 kg/ha of nitrogen, 1816 kg/ha of phosphate, and 215 kg/ha of potash to the area. This would be equivalent to applying 10 mt/ha of a 10-18-2 commercial fertilizer. The value of sludge as a substitute for commercial fertilizer is quite obvious.

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TABLE 51. CHEMICAL ANALYSES OF DEWATERED COMPOSTED SLUDGE APPLIED ON THE WESTMORELAND COUNTY DEMONSTRATION PROJECT

Constituent	Mean	Range	
		Low	High
pH	8.1	7.4	8.5
	----- ppm on dry weight basis -----		
Total P	5871	210	7220
NO_3-N	31	18	88
NH_4-N	551	4	1218
Org-N	6597	3780	10857
Ca	14492	9745	19392
Mg	5237	4417	6621
Na	291	234	325
K	1331	853	2219
Al	10022	7168	11970
Mn	991	666	1230
Fe	1974	1480	2858
Co	3	1	8
Zn	1825	1392	2276
Cu	563	428	685
Pb	437	318	530
Cr	313	210	427
Ni	97	61	140
Cd	1.8	0.7	3.6
Hg	0.46	0.27	0.74
	------------ % ------------		
Total P	0.59	0.02	0.72
Total N	0.72	0.38	1.11
Solids	61.22	50.09	69.35

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TABLE 52. AMOUNTS OF PLANT NUTRIENTS AND TRACE METALS APPLIED ON THE WESTMORELAND COUNTY DEMONSTRATION PROJECT

Constituent	Sludge Application (134 mt/ha)
	kg/ha
Total N	968
P	793
K	179
Cu	76
Zn	245
Cr	42
Pb	59
Ni	13
Co	0.4
Cd	0.2
Hg	0.06

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TABLE 53. COMPARISON OF TRACE METAL LOADINGS AT THE WESTMORELAND COUNTY DEMONSTRATION PROJECT WITH EPA AND PDER RECOMMENDATIONS

Constituent	Sludge Application 134 mt/ha	Recommendations	
		EPA (CEC >15)*	PDER
	kg/ha	kg/ha	kg/ha
Cd	0.2	22	3
Cu	76	560	112
Cr	42	NR†	112
Pb	59	2240	112
Hg	0.06	NR†	0.6
Ni	13	560	22
Zn	245	1120	224

* Average CEC of site ranged from 16.7 to 19.0 meq/100g.

† No recommendation given by EPA.

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SITE PREPARATION

Pre-treatment surface soil samples were analyzed for pH and buffer pH to determine the liming requirements. Results indicated that the average soil pH was 4.3. Thirteen metric tons of agricultural lime per hectare were applied on September 24 and 25 to adjust the soil pH to 7.0.

SLUDGE APPLICATION

On September 24 and 25, 1979, the composted sludge was transported by 20-ton capacity coal trucks from the City of Philadelphia Water Pollution Control Plant to the site (450 km) on a return trip after delivering coal. A total of 903 wet metric tons of sludge at 61.22 percent solids, was delivered to the site. The sludge was loaded with a front end loader into rear-delivery manure spreaders and spread on the site; this was completed on September 26, 1979. Immediately after the spreading, the area was disked to incorporate the sludge into the surface 10 cm of soil material.

6-1/2"

VEGETATION SEEDING

After the incorporation of the sludge, the area was broadcast seeded within a tractor-mounted box seeder on September 26, 1979. The seed mixture used was:

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	kg/ha
Kentucky 31 tall fescue	11
Birdsfoot trefoil	6
Winter Rye	63
Total	80

Completion of seeding by October 1, 1979 would allow approximately 6 to 8 weeks for vegetation growth to become winter hardy.

RESULTS

Vegetation Growth Responses

A site inspection on November 29, 1979, approximately 8 weeks after seeding, indicated that a protective cover of winter rye had been established. Vegetation was approximately 5 cm in height. There was no evidence of any erosion on the sludge treatment area. It appeared that sufficient vegetation was established to protect the site from erosion and runoff over the winter season. This was confirmed by a site inspection on March 28, 1980. The entire sludge-treated area was covered by a vegetative cover ranging from 5

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to 10 cm in height. On the basis of ocular estimates, the percentage areal cover ranged from 80 to 90 percent. There was no evidence of surface runoff or erosion from the sludge-treated area. However, some erosion did occur from barren areas upslope of the sludge-treated area. The sediment-laden surface runoff from these areas was dispersed as soon as it encountered the sludge-treated plot which had been roughened by contour chisel plowing to incorporate the sludge. As soon as the site is dry enough, the remaining portion of the seeding mixture will be broadcast. The following spring seeding mixture will be used:

	kg/ha
Orchardgrass	11
Birdsfoot trefoil	6

Percolate Water Quality

Results of the analyses of soil percolate water samples are given in Tables 54 and 55. Concentrations of NO_3-N in the percolate were extremely low before sludge application and remained at these low levels following sludge application. There was also no apparent effect on trace metal concentrations following sludge application. Concentrations of all elements except Pb meet USPHS drinking water standards. Lead concentrations exceeded these standards on both the control and sludge-treated areas.

Groundwater Quality

Results of the analyses of groundwater well samples are given in Tables 56 and 57. Water level depth in Well 1 fluctuated between 1.7 and 1.8 m during the period of sampling. Sludge application did not have any apparent effect on the concentration of any constituents. The concentration of NO_3-N in Well 1 was slightly higher than the potable water standard (17 mg/l vs 10 mg/l). However, it decreased to 7.1 mg/l during the first month following sludge application and remained at a low level during the period of sampling. Concentrations of all trace metals except Pb were below the maximum allowable limits for potable water. Lead concentrations exceeded the USPHS standards on both the control and sludge-treated area.

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TABLE 54. SOIL PERCOLATE ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE WESTMORELAND COUNTY DEMONSTRATION PROJECT DURING 1979 and 1980

Sludge Application	Month* and Year	Ortho P	NO_3-N	NH_4-N	Org-N	pH
mt/ha		------------	------------	mg/l	------------	------------
0	Aug 1979	0.100	1.3	0.88	0.44	3.2
	Sept 1979	0.083	1.4	0.94	0.68	3.1
	Oct 1979	0.049	1.3	0.77	0.24	3.1
	Nov 1979	0.020	<0.5	0.20	0.05	3.2
	Dec 1979	0.007	<0.5	1.39	0.30	3.2
	Jan 1980	0.011	<0.5	0.40	0.22	3.2
134	Aug 1979	0.130	1.8	3.69	1.12	3.5
	Sept 1979	0.039	0.7	0.85	0.73	3.2
	Oct 1979	0.047	0.8	1.73	0.19	3.5
	Nov 1979	0.037	0.6	0.91	0.90	3.5
	Dec 1979	0.024	<0.5	1.61	0.01	3.4
	Jan 1980	0.038	0.6	0.70	0.19	3.5

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* August and September values represent pre-treatment conditions.

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TABLE 55. SOIL PERCOLATE ANALYSES FOR TRACE METALS AT THE WESTMORELAND COUNTY DEMONSTRATION PROJECT DURING 1979 AND 1980

Sludge Application	Month* and Year	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha		mg/l						
0	Aug, 79	0.64	2.99	0.02	0.06	0.73	0.006	0.42
	Sept, 79	0.23	3.14	0.04	0.06	1.01	0.005	1.05
	Oct, 79	0.19	2.82	0.01	0.06	0.63	0.012	0.77
	Nov, 79	0.16	2.70	0.02	0.05	0.18	0.011	0.82
	Dec, 79	0.26	4.43	0.02	0.07	1.25	0.012	1.46
	Jan, 80	0.16	2.45	0.01	0.07	0.83	0.015	0.84
134	Aug, 79	0.12	4.25	0.02	0.05	1.40	0.010	0.88
	Sept, 79	0.11	3.16	0.12	0.06	1.03	0.005	0.93
	Oct, 79	0.11	3.39	0.01	0.08	0.75	0.008	0.82
	Nov, 79	0.09	3.12	0.01	0.06	0.36	0.011	0.92
	Dec, 79	0.10	3.73	0.01	0.25	2.83	0.007	0.93
	Jan, 80	0.11	3.36	0.01	0.08	1.13	0.017	0.86
USPHS Drinking Water Standards		1.0	5.0	0.05	0.05	5.0†	0.01	2.0†

* August and September values represent pre-treatment conditions.

† No limits given for drinking water standards; these are recommended values for irrigation water for agricultural use.

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TABLE 56. GROUNDWATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE WESTMORELAND COUNTY DEMONSTRATION PROJECT DURING 1979 AND 1980

Well No.	Month* and Year	Ortho P	NO_3-N	NH_4-N	Org-N	pH
		mg/l				
Well 1	Sept 1979	0.015	17.6	0.54	0.62	10.3
	Oct 1979	0.033	7.1	0.72	0.63	11.9
	Nov 1979	0.013	<0.5	1.68	0.00	11.5
	Dec 1979	0.015	<0.5	0.52	0.76	11.8
	Jan 1980	0.007	<0.5	0.75	0.33	11.4
Well 2	Sept 1979	0.004	1.7	0.63	0.58	7.5
	Oct 1979	0.005	1.0	0.66	0.49	7.7
	Nov 1979	<0.001	<0.5	1.64	0.00	7.2
	Dec 1979	0.005	<0.5	0.64	0.48	7.1
	Jan 1980	0.005	<0.5	0.70	0.54	7.0

* September values represent pre-treatment conditions.

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TABLE 57. GROUNDWATER ANALYSES FOR TRACE METALS AT THE WESTMORELAND COUNTY DEMONSTRATION PROJECT DURING 1979 AND 1980

Well No.	Month[*] and Year	Cu	Zn	Cr	Pb	Co	Cd	Ni
		mg/l						
Well 1	Sept, 79	0.05	0.23	0.03	0.14	0.03	<0.001	0.05
	Oct, 79	0.11	0.22	0.02	0.27	0.06	<0.001	0.06
	Nov, 79	0.07	0.14	0.02	0.14	0.01	<0.001	0.05
	Dec, 79	0.09	1.05	0.02	0.14	0.06	<0.001	0.07
	Jan, 80	0.04	0.30	0.01	0.20	0.02	0.001	0.03
Well 2	Sept, 79	0.02	0.17	0.02	0.03	0.24	<0.001	0.17
	Oct, 79	0.03	0.11	0.01	0.07	0.04	<0.001	0.04
	Nov, 79	0.01	0.01	<0.01	0.07	<0.01	0.001	0.07
	Dec, 79	0.01	0.36	0.01	0.07	0.02	<0.001	0.01
	Jan, 80	<0.01	0.12	<0.01	0.08	0.10	0.001	0.04
USPHS Drinking Water Standards		1.0	5.0	0.05	0.05	5.0[†]	0.01	2.0[†]

[*] September values represent pre-treatment conditions.

[†] No limits given for drinking water standards; these are recommended values for irrigation water for agricultural use.

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REFERENCES

1. Baker, D. E., G. W. Gorsline, C. B. Smith, W. I. Thomas, W. E. Grube, and R. L. Ragland. 1964. Technique of rapid analyses of corn leaves for eleven elements. Agronomy Journal: 56:133-136.

2. Council for Agricultural Science and Technology. 1976. Application of Sewage Sludge to Cropland: Appraisal of Potential Hazards of the Heavy Metals to Plants and Animals. Office of Water Programs, U.S. Environmental Protection Agency, EPA-430/9-76-013, 63 pp.

3. Ellis, Boyd G. 1976. Analyses and their Interpretation for Wastewater Application on Agricultural Land. North Central Regional Research Publication 235-Section 6.

4. Gaseous Fuels; Coal and Coke; Atmospheric Analysis. 1976. American Society for Testing and Materials, Phila., Pa.

5. Hill, R. D. and A. Montague. 1976. The Potential for Using Sewage Sludges and Compost in Mine Reclamation, Sludge Management Disposal and Utilization, Information Transfer, Inc., pp. 39-45.

6. Jackson, M. L. 1958. Soil Chemical Analysis. Prentice-Hall, Inc., Englewood Cliffs, N.J.

7. League of Women Voters. 1976. Municipal Sludge: What Shall We Do With It? Current Focus. Pub. No. 627, Washington, D.C., 8 pp.

8. Melsted, S. W. 1973. Soil-Plant Relationships (Some Practical Considerations in Waste Management), Recycling Municipal Sludges and Effluents on Land. National Association of State Universities and Land-Grant Colleges, Washington, D.C., pp. 121-128.

9. Methods for Chemical Analysis of Water and Wastes. U.S. Environmental Protection Agency, Washington, D.C., 1974.

10. Pennsylvania Department of Environmental Resources. 1977. Interim Guidelines for Sewage Sludge Use for Land Reclamation, In The Rules and Regulations of the Department of Environmental Resources, Commonwealth of Pennsylvania, Chapter 75, Subchapter C, Section 75.32.

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11. Pennsylvania Department of Environmental Resources. 1977. Interim Guidelines for Sewage, Septic Tank, and Holding Tank Waste Use on Agricultural Land, In The Rules and Regulations of the Department of Environmental Resources, Commonwealth of Pennsylvania, Chapter 75, Subchapter C, Section 75.32.

12. Standard Methods for the Examination of Water and Wastewater. 1976. 14th Ed., American Public Health Assn., Washington, D.C.

13. Strip and Surface Mine Study Policy Committee. 1967. Surface Mining and Our Environment. A Special report to the Nation, U.S. Department of the Interior, 124 pp.

14. U.S. Environmental Protection Agency. 1977. Municipal Sludge Management: Environmental Factors. Technical Bulletin EPA 430/9-76-004, MCD-28.

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APPENDIX. ANALYTICAL METHODS: PERCOLATE, GROUNDWATER WELLS, LAKES

pH

The samples were analyzed for pH by direct reading on a pH meter.

Nitrate-Nitrogen

Samples were analyzed for nitrate-nitrogen using an ion-selective electrode as described by Ellis (1976).

Chloride

An ion-selective electrode was used for the determination of chloride as described by Ellis (1976).

Ammonium Nitrogen

A gas sensing electrode was used for the determination of ammonium nitrogen as described in the EPA Methods of Chemical Analysis (1974).

Organic Nitrogen

Organic nitrogen was determined using the selenium digestion procedure described in EPA Methods of Chemical Analysis (1974).

Ortho Phosphorus

Ortho phosphorus was determined using blue colorimetric procedure described by Jackson (1958).

Sulfate

Sulfate was determined using the Turbidimetric method described in Standard Methods (1976).

Metals

A subsample was acidified at the time of collection and analyzed for dissolved metals as described in EPA Methods of Chemical Analysis (1974).

Bacteria

Fecal and total coliforms were monitored using the method described in Standard Methods (1976).

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Sludge

The same methods used for the percolate samples were employed for the determination of pH, nitrate-nitrogen, ammonium-nitrogen and chloride in the sludge.

Total Phosphorus

Total phosphorus was determined using the vanadium method as described by Jackson (1958).

Metals

The sludge was analyzed for metals using a modification of the hydrochloric nitric acid digestion procedure described in EPA Methods of Chemical Analysis (1974), followed by reading on an atomic absorption spectrophotometer.

Mercury

Mercury was determined using the cold vapor method described in EPA Methods of Chemical Analysis (1974).

Soil Samples

pH

Soil samples were analyzed for pH by mixing 5 gm of <2 mm refuse material and 5 ml of distilled water, allowing the slurry to stand 15 minutes, re-mixing, allowing the slurry to stand 15 minutes more, re-mixing, and reading pH on a Fisher Accument Model 210 pH meter.

Exchangeable Cations

Exchangeable calcium, potassium, sodium, and magnesium were determined on the <2 mm fraction by the alternate ammonium acetate extraction method described by Jackson (1958).

Extractable Cations

Extractable iron, aluminum and manganese were determined by the potassium chloride extraction process described by Jackson (1958).

Soil Phosphorus

Soil phosphorus was determined by a modification of the Bray method (0.03N-NH_4F in 0.025-HCl) described by Jackson (1958).

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Kjeldahl Nitrogen

Soil nitrogen was determined using the modified Kjeldahl method described by Jackson (1958).

Total Sulfur

Total sulfur was determined using the high-temperature combustion method described in ASTM Standards (1976).

Extractable Heavy Metals

Extractable copper, zinc, chromium, cobalt, lead, cadmium, and nickel were determined using the dilute hydrochloric extraction procedure described by Jackson (1958).

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TABLE A-1. SOIL ANALYSIS FOR pH, KJELDAHL NITROGEN, TOTAL SULFUR AND BRAY PHOSPHORUS FOR SAMPLES COLLECTED 5/77, PRIOR TO SLUDGE APPLICATION, FROM THE VENANGO DEMONSTRATION PROJECT

Sludge Application	Soil Depth	pH	Kjeldahl Nitrogen	Total Sulfur	Bray Phosphorus
mt/ha	cm		%	%	µg/g
0	0 - 15	3.4	0.04	0.08	0.60
	15 - 30	3.8	0.05	0.08	0.78
	30 - 60	4.0	0.08	0.04	1.47
	60 - 90	4.0	0.05	0.04	3.07
7	0 - 15	6.2	0.03	0.06	2.33
	15 - 30	7.4	0.03	0.04	4.25
	30 - 60	7.5	0.02	0.04	2.33
	60 - 90	7.3	0.02	0.04	2.68
11-L	0 - 15	4.2	0.05	0.22	2.83
	15 - 30	4.2	0.05	0.37	1.60
	30 - 60	3.6	0.04	0.39	0.67
	60 - 90	3.8	0.04	0.24	1.43
90	0 - 15	3.7	0.05	0.16	1.97
	15 - 30	3.4	0.05	0.12	2.43
	30 - 60	3.9	0.04	0.17	3.48
	60 - 90	3.3	0.04	0.28	5.32
90-L	0 - 15	3.2	0.04	0.24	1.00
	15 - 30	3.0	0.05	0.29	0.30
	30 - 60	3.0	0.05	0.35	0.48
	60 - 90	3.1	0.05	0.38	1.42
184	0 - 15	3.4	0.04	0.12	3.57
	15 - 30	3.3	0.05	0.19	3.28
	30 - 60	3.4	0.06	0.24	3.47
	60 - 90	3.4	0.05	0.26	3.40
184-L	0 - 15	4.6	0.03	0.13	2.05
	15 - 30	4.8	0.03	0.17	2.38
	30 - 60	3.4	0.04	0.31	2.22
	60 - 90	3.2	0.04	0.33	1.47

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TABLE A-2. PRE-TREATMENT SOIL ANALYSES FOR CATIONS AND HEAVY METALS COLLECTED 5/77 FROM THE VENANGO COUNTY DEMONSTRATION PROJECT

Sludge Application	Soil Depth	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha	cm				µg/g			
0	0 - 15	59	3	278	14	217	496	20
	15 - 30	79	3	289	14	439	812	22
	30 - 60	33	3	245	14	763	1186	21
	60 - 90	98	5	216	15	369	653	21
7	0 - 15	52	3	281	26	3421	474	28
	15 - 30	50	3	273	25	1480	588	24
	30 - 60	54	4	289	22	1059	523	28
	60 - 90	81	5	188	18	1023	462	27
11-L	0 - 15	32	3	260	11	5952	225	23
	15 - 30	29	3	209	11	1333	335	23
	30 - 60	56	3	211	10	1710	501	19
	60 - 90	202	3	222	11	1101	412	30
90	0 - 15	20	10	26	13	93	291	27
	15 - 30	24	7	95	12	111	29	29
	30 - 60	24	13	108	17	968	699	29
	60 - 90	25	11	115	17	1342	1365	27
90-L	0 - 15	19	2	14	7	857	838	23
	15 - 30	18	2	14	9	965	1069	29
	30 - 60	19	2	14	7	1350	1152	25
	60 - 90	20	2	14	8	1962	1155	27
184	0 - 15	60	9	219	13	213	174	26
	15 - 30	34	8	175	15	407	563	28
	30 - 60	38	15	221	18	847	683	29
	60 - 90	95	8	149	20	1264	787	30
184-L	0 - 15	40	3	226	15	1327	459	12
	15 - 30	56	3	186	10	753	424	18
	30 - 60	77	3	180	11	752	831	12
	60 - 90	83	3	189	9	930	926	15

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TABLE A-2. (Continued)

Sludge Application	Soil Depth	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha	cm	- - - - -	- - - - -	- - - - -	-µg/g -	- - - - -	- - - - -	- - - - -
0	0 - 15	2.7	2.0	0.1	0.7	0.4	0.01	0.7
	15 - 30	4.5	3.3	0.2	0.7	0.7	0.05	1.0
	30 - 60	7.1	4.6	0.3	1.0	0.9	0.10	1.3
	60 - 90	3.8	2.8	0.1	1.1	0.5	0.01	0.7
7	0 - 15	2.7	2.3	0.1	1.8	1.3	0.03	0.5
	15 - 30	5.6	3.5	0.1	1.9	1.2	0.03	1.1
	30 - 60	5.4	3.3	0.1	1.5	0.9	0.02	0.7
	60 - 90	3.3	2.9	0.1	1.7	0.9	0.01	0.8
11-L	0 - 15	1.5	2.1	0.2	0.7	0.9	0.02	1.1
	15 - 30	2.2	1.8	0.1	0.4	0.5	0.04	0.6
	30 - 60	2.0	2.1	0.1	0.7	0.7	0.03	0.9
	60 - 90	2.2	2.4	0.1	0.9	0.8	0.02	0.9
90	0 - 15	2.0	1.6	0.1	0.4	0.3	0.03	0.6
	15 - 30	2.2	2.5	0.1	0.4	0.4	0.02	0.6
	30 - 60	3.5	2.9	0.1	1.6	0.7	0.02	1.4
	60 - 90	4.5	4.6	0.3	1.7	1.7	0.02	3.0
90-L	0 - 15	2.5	2.6	0.2	0.4	1.0	0.01	1.4
	15 - 30	3.1	2.9	0.2	0.4	1.2	0.01	1.7
	30 - 60	2.8	3.1	0.2	0.5	1.9	0.02	2.3
	60 - 90	2.3	2.2	0.1	0.7	1.5	0.01	1.7
184	0 - 15	2.2	1.3	0.1	0.5	0.4	0.01	0.4
	15 - 30	3.0	1.9	0.1	1.1	1.0	0.01	1.1
	30 - 60	3.1	1.8	0.1	1.2	0.9	0.01	1.3
	60 - 90	3.2	1.7	0.1	1.3	0.7	0.01	1.2
184-L	0 - 15	4.0	5.6	0.2	0.5	1.3	0.03	2.4
	15 - 30	3.1	2.2	0.1	0.4	0.6	0.01	1.1
	30 - 60	3.9	3.9	0.2	0.5	1.1	0.01	2.1
	60 - 90	3.4	3.7	0.2	0.5	1.2	0.01	2.1

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TABLE A-3. ANALYSES OF SOIL SAMPLES COLLECTED FROM THE VENANGO DEMONSTRATION PROJECT FOR pH, KJELDAHL NITROGEN, TOTAL SULFUR, AND BRAY PHOSPHORUS FOUR MONTHS AFTER SLUDGE APPLICATION

Sludge Application	Soil Depth	pH	Kjeldahl Nitrogen	Total Sulfur	Bray Phosphorus
mt/ha	cm		%	%	µg/g
7	0 - 15	5.4	0.04	0.13	4.33
	15 - 30	4.7	0.04	0.15	2.67
	30 - 60	5.0	0.05	0.29	2.00
11-L	0 - 15	7.8	0.04	0.12	2.33
	15 - 30	6.7	0.04	0.17	1.17
	30 - 60	5.6	0.04	0.28	1.17
90	0 - 15	3.6	0.05	0.18	2.92
	15 - 30	3.5	0.05	0.36	2.00
	30 - 60	4.6	0.04	0.31	1.58
90-L	0 - 15	6.6	0.09	0.26	7.25
	15 - 30	6.6	0.08	0.39	2.50
	30 - 60	4.2	0.08	0.21	4.17
184	0 - 15	3.9	0.04	0.27	7.50
	15 - 30	3.8	0.04	0.27	8.00
	30 - 60	3.7	0.04	0.35	6.33
184-L	0 - 15	6.2	0.05	0.08	11.17
	15 - 30	4.2	0.04	0.07	3.67
	30 - 60	4.1	0.06	0.07	3.00

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TABLE A-4. ANALYSES OF SOIL SAMPLES COLLECTED FROM THE VENANGO DEMONSTRATION PROJECT FOR pH, KJELDAHL NITROGEN, TOTAL SULFUR, AND BRAY PHOSPHORUS EIGHTEEN MONTHS AFTER SLUDGE APPLICATION

Sludge Application	Soil Depth	pH	Kjeldahl Nitrogen	Total Sulfur	Bray Phosphorus
mt/ha	cm		%	%	µg/g
7	0 - 15	6.9	0.08	0.03	2.34
	15 - 30	6.8	0.06	0.03	1.00
	30 - 60	6.8	0.06	0.03	3.34
11-L	0 - 15	5.7	0.08	0.18	2.67
	15 - 30	4.5	0.07	0.42	2.67
	30 - 60	3.5	0.07	0.31	1.00
90	0 - 15	3.4	0.03	0.14	4.00
	15 - 30	3.2	0.03	0.17	1.67
	30 - 60	2.9	0.03	0.28	1.00
90-L	0 - 15	6.6	0.05	0.12	3.34
	15 - 30	6.6	0.04	0.19	1.00
	30 - 60	3.6	0.04	0.14	2.34
184	0 - 15	5.1	0.07	0.10	8.67
	15 - 30	3.6	0.06	0.09	2.34
	30 - 60	3.7	0.06	0.13	2.00
184-L	0 - 15	6.7	0.09	0.07	9.00
	15 - 30	4.6	0.06	0.10	3.67
	30 - 60	4.1	0.07	0.10	2.34

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TABLE A-5. ANALYSES OF SOIL SAMPLES COLLECTED ON THE VENANGO DEMONSTRATION PROJECT FOR EXCHANGEABLE CATIONS AND EXTRACTABLE IRON, ALUMINUM, AND MANGANESE FOUR MONTHS AFTER SLUDGE APPLICATION

Sludge Application	Soil Depth	K	Ca	Mg	Na	Fe	Mn	Al
mt/ha	cm	- - - - - - - - -	- - -	-µg/g	- - -	- - - - - - - - - -		
7	0 - 15	20	1206	69	38	13.2	18.1	35.4
	15 - 30	19	1195	70	35	13.7	23.2	56.3
	30 - 60	17	1850	91	35	14.7	21.1	38.4
11-L	0 - 15	25	644	53	41	13.7	3.8	32.3
	15 - 30	21	672	69	37	16.3	4.0	56.6
	30 - 60	35	1250	45	37	58.8	4.5	75.3
90	0 - 15	16	484	84	34	22.2	16.7	169.0
	15 - 30	14	906	109	33	33.6	18.3	175.0
	30 - 60	12	851	148	29	121.1	26.4	231.8
90-L	0 - 15	24	2110	61	31	12.1	5.4	23.3
	15 - 30	14	702	72	29	14.2	19.6	71.7
	30 - 60	17	710	111	30	13.2	48.7	68.5
184	0 - 15	19	503	63	36	15.3	26.3	139.9
	15 - 30	19	859	92	37	14.7	24.9	156.1
	30 - 60	19	1817	130	35	15.8	25.4	137.8
184-L	0 - 15	19	1222	32	30	12.6	3.3	14.4
	15 - 30	14	342	35	32	16.9	5.4	80.7
	30 - 60	18	275	39	28	17.9	7.0	108.7

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TABLE A-6. ANALYSES OF SOIL SAMPLES COLLECTED ON THE VENANGO DEMONSTRATION PROJECT FOR EXCHANGEABLE CATIONS AND EXTRACTABLE IRON, ALUMINUM AND MANGANESE EIGHTEEN MONTHS AFTER SLUDGE APPLICATION

Sludge Application	Soil Depth	K	Ca	Mg	Fe	Mn	Al
mt/ha	cm	- - - - - - - - - -	- - - - - - - - - -	µg/g	- - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - -
7	0 - 15	42.9	2246	87.6	20.0	6.0	18.7
	15 - 30	31.2	1966	68.4	20.7	10.7	35.3
	30 - 60	31.2	1734	96.0	24.7	16.7	80.0
11-L	0 - 15	27.3	2114	56.4	19.3	4.7	9.3
	15 - 30	23.4	2060	68.4	20.0	5.3	23.3
	30 - 60	23.4	1606	108.0	18.7	4.7	6.7
90	0 - 15	24.7	393	48.0	25.3	11.3	121.3
	15 - 30	23.4	993	56.0	26.7	8.7	121.3
	30 - 60	23.4	1313	100.0	53.3	13.3	168.0
90-L	0 - 15	23.4	2466	84.0	20.7	6.0	36.0
	15 - 30	31.2	2280	96.0	21.3	12.0	38.0
	30 - 60	23.4	1460	140.4	23.3	42.0	122.0
184	0 - 15	28.6	780	64.0	20.7	11.3	64.7
	15 - 30	28.6	1067	72.0	24.0	20.0	110.7
	30 - 60	27.3	860	108.0	44.7	10.0	46.7
184-L	0 - 15	23.4	2600	39.6	18.7	4.0	7.3
	15 - 30	23.4	746	32.4	19.3	5.3	38.7
	30 - 60	23.4	446	39.6	20.7	5.3	50.0

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TABLE A-7. ANALYSES OF SOIL SAMPLES COLLECTED ON THE VENANGO DEMONSTRATION PROJECT FOR EXTRACTABLE TRACE METALS FOUR MONTHS AFTER SLUDGE APPLICATION

Sludge Application	Soil Depth	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha	cm				µg/g			
7	0 - 15	3.75	2.32	0.03	1.55	0.64	0.015	1.20
	15 - 30	3.07	3.05	0.03	1.95	0.79	0.012	1.40
	30 - 60	2.71	2.79	0.05	1.57	0.85	0.014	1.54
11-L	0 - 15	1.67	1.23	0.04	1.34	0.34	0.021	0.53
	15 - 30	1.46	0.69	0.04	1.07	0.21	0.010	0.35
	30 - 60	1.67	1.02	0.07	0.66	0.25	0.017	0.51
90	0 - 15	6.15	4.75	0.15	1.21	0.56	0.014	1.09
	15 - 30	6.26	10.87	0.14	1.34	0.71	0.017	1.36
	30 - 60	5.94	4.93	0.24	1.09	1.62	0.009	2.23
90-L	0 - 15	13.02	12.90	0.55	3.73	1.00	0.058	1.74
	15 - 30	3.28	2.03	0.12	1.21	0.27	0.009	0.64
	30 - 60	2.97	1.99	0.11	1.19	0.55	0.007	1.08
184	0 - 15	6.05	5.66	0.15	2.08	0.96	0.023	1.27
	15 - 30	4.48	6.90	0.12	2.00	0.92	0.026	2.02
	30 - 60	4.43	6.72	0.17	1.66	1.20	0.019	2.72
184-L	0 - 15	10.85	7.68	0.35	3.51	1.26	0.037	0.87
	15 - 30	4.01	2.03	0.07	1.32	0.19	0.009	0.39
	30 - 60	4.95	2.92	0.09	1.85	0.26	0.013	0.46

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TABLE A-8. ANALYSES OF SOIL SAMPLES COLLECTED 11/78 ON THE VENANGO DEMONSTRATION PROJECT FOR EXTRACTABLE TRACE METALS EIGHTEEN MONTHS AFTER SLUDGE APPLICATION

Sludge Application	Soil Depth	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha	cm				µg/g			
7	0 - 15	3.50	5.17	0.33	1.83	2.17	0.009	1.33
	15 - 30	2.50	2.83	0.17	1.33	1.00	0.008	1.50
	30 - 60	2.00	2.33	<0.01	1.00	0.83	0.002	1.00
11-L	0 - 15	2.67	2.33	<0.01	1.67	0.83	0.016	0.67
	15 - 30	3.17	3.00	<0.01	2.00	1.00	0.015	1.17
	30 - 60	2.00	1.67	<0.01	1.67	0.50	0.010	0.83
90	0 - 15	6.17	3.17	<0.01	1.50	0.17	0.010	0.67
	15 - 30	2.17	1.83	<0.01	0.67	0.33	0.006	0.50
	30 - 60	2.83	2.67	0.33	0.67	0.50	0.002	1.00
90-L	0 - 15	2.50	1.83	0.17	1.67	0.67	0.007	1.33
	15 - 30	2.67	4.50	0.17	1.00	1.17	0.010	2.83
	30 - 60	2.67	3.17	<0.01	1.33	1.17	0.007	2.33
184	0 - 15	10.17	7.17	0.17	3.50	0.83	0.026	1.50
	15 - 30	3.67	2.67	<0.01	1.83	0.83	0.010	1.00
	30 - 60	3.33	2.50	<0.01	1.83	0.50	0.007	0.83
184-L	0 - 15	8.83	7.67	0.17	2.33	1.17	0.017	1.17
	15 - 30	2.50	1.67	<0.01	1.33	0.50	0.007	0.67
	30 - 60	1.83	1.83	<0.01	1.50	0.50	0.008	0.67

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TABLE A-9. MEAN FOLIAR CONCENTRATIONS OF SELECTED CONSTITUENTS IN SAMPLES COLLECTED IN 1977 FROM THE VENANGO DEMONSTRATION PROJECT

Species	Sludge Application	N	P	K	Ca	Mg	Mn	Fe	B	Al
	mt/ha			%				µg/g		
Birdsfoot Trefoil	7	3.76	0.22	1.40	2.43	0.40	97	73	46	46
	11-L	3.42	0.19	1.06	2.13	0.39	110	65	35	75
	90	3.68	0.28	1.60	2.21	0.33	328	112	65	58
	90-L	3.76	0.25	1.48	2.22	0.29	158	85	61	48
	184	3.60	0.32	1.43	1.81	0.34	529	91	61	68
	184-L	3.64	0.27	1.46	1.99	0.28	165	93	54	50
Crownvetch	7	3.92	0.25	1.40	2.37	0.44	129	59	30	35
	11-L	3.72	0.25	1.12	2.35	0.39	163	63	31	44
	90	2.76	0.26	1.43	2.47	0.49	661	191	45	72
	90-L	3.80	0.28	1.47	2.75	0.41	427	171	41	75
	184	2.64	0.26	1.48	2.13	0.45	687	150	35	70
	184-L	3.36	0.34	1.64	2.63	0.42	381	246	48	74
Tall Fescue	0	1.08	0.16	1.35	0.44	0.20	242	626	17	1000
	7	1.38	0.21	2.11	0.49	0.27	150	87	14	72
	11-L	1.74	0.25	2.33	0.68	0.29	159	120	18	46
	90	2.20	0.36	2.96	0.53	0.34	411	116	17	81
	90-L	1.98	0.29	2.75	0.62	0.33	199	84	12	18
	184	2.42	0.45	2.87	0.64	0.33	390	84	16	20
	184-L	2.32	0.37	3.39	0.62	0.28	243	124	16	40
Orchard-grass	7	1.40	0.29	1.96	0.80	0.30	359	80	13	37
	11-L	1.76	0.29	2.11	1.13	0.36	247	104	16	47
	90	2.38	0.38	2.72	0.80	0.35	766	95	14	26
	90-L	2.18	0.44	2.72	0.80	0.31	265	104	16	40
	184	2.85	0.53	2.84	0.83	0.36	786	148	18	24
	184-L	2.62	0.40	2.84	0.84	0.31	225	68	9	30

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TABLE A-10. MEAN FOLIAR CONCENTRATIONS OF TRACE METALS IN SAMPLES COLLECTED IN 1977 FROM THE VENANGO DEMONSTRATION PROJECT

Species	Sludge Application	Cu	Zn	Cr	Pb	Co	Cd	Ni
	mt/ha				µg/g			
Birdsfoot Trefoil	7	11.6	37.0	0.7	7.7	1.9	0.14	3.3
	11-L	10.7	39.0	0.8	7.0	1.8	0.13	3.9
	90	12.9	94.7	0.8	7.7	2.4	0.42	7.5
	90-L	12.5	107.6	1.0	7.0	2.2	0.52	6.3
	184	13.1	113.8	1.0	6.9	2.4	0.32	8.9
	184-L	13.9	95.9	1.0	7.4	2.1	0.43	6.3
Crownvetch	7	8.6	38.1	0.5	8.8	2.7	0.11	4.4
	11-L	9.4	34.0	0.5	9.0	2.0	0.10	3.5
	90	10.2	57.1	0.6	8.5	2.0	0.20	6.2
	90-L	10.2	117.6	1.1	7.2	2.4	0.43	11.4
	184	8.6	44.5	0.9	7.2	2.3	0.19	6.5
	184-L	9.4	74.7	0.8	7.4	2.7	0.27	10.4
Tall Fescue	0	10.2	23.2	0.9	10.9	1.5	0.52	3.1
	7	5.5	24.5	0.5	3.7	0.8	0.10	3.0
	11-L	6.3	23.2	0.5	5.1	1.1	0.18	2.5
	90	11.7	36.0	0.5	4.8	1.7	0.23	5.7
	90-L	12.5	57.1	0.4	6.6	2.1	0.25	7.6
	184	8.6	28.5	0.8	4.3	1.7	0.15	4.3
	184-L	9.4	48.8	0.8	4.5	1.5	0.20	9.8
Orchard-grass	7	10.4	38.0	0.5	4.7	1.3	0.16	3.0
	11-L	8.8	40.1	0.7	4.9	1.1	0.15	2.8
	90	15.7	91.5	0.6	4.7	1.7	0.15	7.6
	90-L	19.1	69.7	0.7	5.9	1.3	0.24	5.5
	184	20.4	93.7	0.9	5.3	1.7	0.29	6.4
	184-L	21.4	76.7	0.9	5.4	1.6	0.24	5.5

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TABLE A-11. MEAN FOLIAR CONCENTRATIONS OF SELECTED CONSTITUENTS IN SAMPLES COLLECTED IN 1978 FROM THE VENANGO DEMONSTRATION PROJECT

Species	Sludge Application	N	P	K	Ca	Mg	Mn	Fe	B	Al
	mt/ha			%				µg/g		
Birdsfoot Trefoil	0	1.03	0.24	1.93	0.61	0.26	914	739	12.6	577
	7	1.33	0.36	2.26	0.65	0.24	206	198	6.9	120
	11-L	1.72	0.35	2.51	0.78	0.27	234	286	8.1	148
	90	1.07	0.37	2.08	0.53	0.23	1232	206	12.7	120
	90-L	1.09	0.36	2.08	0.57	0.22	727	177	10.3	101
	184	1.15	0.37	1.94	0.51	0.22	1021	179	11.6	113
	184-L	1.27	0.36	2.30	0.59	0.25	527	158	8.7	106
Crownvetch	7	3.14	0.32	2.62	0.97	0.80	136	351	8.6	166
	11-L	2.52	0.29	2.33	0.86	0.54	200	546	9.8	423
	90	2.77	0.30	2.92	0.82	0.33	100	376	7.8	205
	90-L	3.09	0.32	2.84	0.94	0.36	119	507	8.0	227
	184	3.03	0.38	2.82	1.09	0.37	319	637	10.5	354
	184-L	2.35	0.37	3.14	0.96	0.45	451	369	11.5	373
Tall Fescue	0	2.73	0.23	1.95	0.93	0.31	63	553	9.5	213
	7	3.91	0.31	1.93	3.35	1.03	245	276	75.3	136
	11-L	3.59	0.27	1.96	2.88	0.92	266	323	65.3	177
	90	3.02	0.26	1.94	1.14	0.37	84	885	9.8	337
	90-L	2.78	0.24	2.14	1.03	0.33	171	541	9.8	235
	184	2.17	0.23	3.00	0.53	0.19	382	430	11.1	481
	184-L	2.66	0.32	2.67	1.48	0.51	453	618	32.2	634
Orchard-grass	0	0.92	0.18	1.51	0.36	0.23	327	812	8.8	698
	7	1.01	0.25	1.63	0.48	0.21	114	184	5.3	121
	11-L	1.73	0.26	2.17	0.66	0.25	106	226	7.1	125
	90	0.62	0.17	1.02	0.26	0.14	392	357	6.9	113
	90-L	0.85	0.22	1.01	0.35	0.19	421	174	7.4	107
	184	1.58	0.41	1.94	0.48	0.29	584	228	9.2	137
	184-L	1.26	0.37	2.01	0.49	0.28	149	159	6.2	104

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TABLE A-12. MEAN FOLIAR CONCENTRATION OF TRACE METALS IN SAMPLES COLLECTED IN 1978 FROM THE VENANGO DEMONSTRATION PROJECT

Species	Sludge Application	Co	Zn	Cr	Pb	Co	Cd	Ni
	mt/ha				µg/g			
Birdsfoot Trefoil	0	7.7	32.2	0.3	8.6	2.6	0.14	7.4
	7	8.2	31.5	0.3	8.1	0.9	0.06	3.5
	11-L	7.7	29.0	0.3	7.5	1.8	0.07	4.3
	90	7.3	65.1	0.3	7.2	2.2	0.27	7.5
	90-L	7.9	46.1	0.3	8.1	2.0	0.12	6.2
	184	7.9	42.7	0.3	7.2	2.3	0.10	5.1
	184-L	7.7	30.4	0.3	8.5	3.0	0.07	4.8
Crownvetch	7	7.4	45.6	0.4	8.5	2.8	0.11	3.1
	11-L	7.0	32.7	0.4	9.3	3.1	0.09	4.1
	90	7.8	111.0	0.3	9.5	2.4	0.44	4.8
	90-L	7.1	75.0	0.3	8.6	2.2	0.33	4.0
	184	7.9	102.7	0.5	8.8	2.8	0.48	4.7
	184-L	8.6	68.5	0.3	8.6	2.4	0.28	4.8
Tall Fescue	0	5.7	24.9	0.7	8.8	1.8	0.27	4.8
	7	3.4	22.9	0.4	7.8	1.3	0.19	2.3
	11-L	5.0	20.7	0.6	4.2	1.4	0.11	2.6
	90	7.4	43.7	0.5	4.0	1.9	0.18	3.1
	90-L	4.7	28.8	0.4	5.0	1.3	0.34	2.0
	184	11.0	83.6	1.3	4.4	2.5	0.45	11.7
	184-L	8.6	44.4	0.8	4.5	1.6	0.41	3.7
Orchard-grass	0	6.1	27.2	0.7	6.8	3.7	0.14	5.7
	7	5.4	32.0	0.6	6.8	1.5	0.27	2.5
	11-L	6.2	33.3	0.6	6.5	1.3	0.28	4.3
	90	5.5	87.1	0.6	5.8	2.7	0.31	7.7
	90-L	9.9	51.7	0.7	6.2	2.2	0.52	4.1
	184	8.2	99.0	0.6	6.5	3.2	0.35	9.0
	184-L	6.9	63.5	0.6	8.3	2.8	0.50	4.3

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TABLE A-13. MEAN FOLIAR CONCENTRATIONS OF TRACE METALS IN SAMPLES COLLECTED IN 1979 FROM THE VENANGO DEMONSTRATION PROJECT

Species	Sludge Application	Cu	Zn	Cr	Pb	Co	Cd	Ni
	mt/ha	- - - - - - - - - - - -	- - - - -	-μg/g - - - -	- - - -	- - - -	- - - -	- - - -
Birdsfoot Trefoil	0	8.4	38.0	8.5	2.6	0.6	0.10	21.4
	7	9.9	33.8	2.0	3.5	0.1	0.10	7.4
	11-L	8.3	33.2	1.0	3.3	0.8	0.03	4.5
	90-L	8.9	46.2	8.3	1.8	0.4	0.11	15.2
	184	9.8	74.8	0.3	4.4	0.8	0.06	11.3
	184-L	9.2	41.5	1.7	1.8	0.3	0.04	6.3
Crownvetch	7	8.4	49.2	10.3	5.3	1.1	0.11	12.1
	11-L	7.4	35.3	5.4	5.1	0.9	0.05	7.8
	90-L	9.1	58.2	24.4	1.9	2.1	0.05	37.3
	184	10.9	132.6	0.3	3.6	1.2	0.16	5.5
	184-L	8.8	70.9	26.2	2.3	1.3	0.09	33.9
Tall Fescue	0	3.3	9.4	22.4	1.8	0.6	0.06	31.0
	7	5.8	20.9	0.1	3.7	1.0	0.08	0.5
	11-L	5.3	21.8	< 0.1	3.0	0.3	0.06	0.8
	90-L	5.3	24.8	8.6	2.8	1.3	0.08	13.0
	184	5.3	48.6	0.3	1.2	0.1	0.06	2.2
	184-L	9.2	72.5	0.5	1.8	0.6	0.08	2.5
Orchard-grass	0	12.4	24.8	7.1	2.4	0.5	0.08	11.8
	7	8.3	28.3	15.1	4.9	0.4	0.10	20.4
	11-L	9.3	27.8	15.4	3.3	0.5	0.05	20.9
	90-L	9.9	44.3	14.6	2.1	0.8	0.15	19.1
	184	9.3	96.1	0.3	1.6	0.4	0.10	5.8
	184-L	8.4	56.9	4.6	3.7	0.3	0.19	8.0

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TABLE A-14. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO DEMONSTRATION PROJECT FOR 1977

Sludge Application	Month	Ortho P	NO_3-N	NH_4-N	Org-N	Cl	pH
mt/ha		mg/l					
0	May	0.075	1.8	3.42	0.05	13.4	4.3
	June	0.158	2.8	1.27	0.05	12.0	3.4
	July	0.097	2.6	1.40	0.35	4.6	3.3
	Aug	0.033	1.2	1.18	1.70	4.1	3.4
	Sept	0.030	1.8	1.54	0.19	4.4	3.6
	Oct	0.020	1.9	1.24	1.19	4.3	3.7
	Nov	0.041	0.5	0.32	1.89	1.5	3.7
7	May	0.578	4.0	0.38	1.94	51.1	7.3
	June	0.255	15.5	0.19	0.41	37.2	7.2
	July	0.137	16.5	0.10	0.17	20.1	7.4
	Aug	0.090	3.1	0.16	0.37	7.8	7.2
	Sept	0.070	3.5	0.42	0.20	3.7	7.4
	Oct	0.043	4.4	0.06	0.27	2.2	7.4
	Nov	0.030	0.5	0.08	0.30	0.8	7.3
11-L	May	0.078	2.6	1.76	1.86	58.3	4.4
	June	0.044	33.9	14.07	--	33.0	4.4
	July	0.033	32.8	6.34	0.88	30.0	4.7
	Aug	0.032	4.9	1.90	0.49	12.4	5.0
	Sept	0.023	7.7	0.36	0.14	5.8	5.8
	Oct	0.014	2.3	0.18	0.28	4.3	5.6
	Nov	0.008	0.7	0.23	0.19	4.2	5.0
90	May	0.104	2.7	1.75	2.38	30.6	3.6
	June	0.138	1.9	5.50	--	7.4	3.2
	July	0.084	11.2	6.82	6.73	11.3	3.2
	Aug	0.045	7.6	5.89	0.22	8.1	3.7
	Sept	0.033	7.0	4.09	--	5.4	3.7
	Oct	0.029	5.1	3.39	--	3.3	3.7
	Nov	0.018	0.7	0.61	0.23	1.0	3.9
90-L	May	0.109	2.4	1.08	7.73	29.7	3.7
	June	0.327	2.8	1.60	0.05	8.6	2.9
	July	0.123	16.3	2.91	0.05	13.2	3.2
	Aug	0.068	13.9	3.02	0.10	11.2	3.4
	Sept	0.045	5.0	4.97	0.40	6.0	3.4
	Oct	0.028	2.1	2.12	0.36	3.0	3.6
	Nov	0.020	0.5	1.79	0.37	0.5	3.7

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TABLE A-14. (Continued)

Sludge Application	Month	Ortho P	NO_3-N	NH_4-N	Org-N	Cl	pH
mt/ha				mg/l			
184	May	0.199	1.9	1.75	2.32	25.8	4.2
	June	0.170	2.9	3.23	7.00	11.4	3.3
	July	0.103	7.5	7.97	2.84	14.4	3.4
	Aug	0.070	10.0	9.11	2.15	8.0	3.5
	Sept	0.054	9.9	10.00	--	6.2	3.4
	Oct	0.037	7.6	5.31	--	3.4	3.6
	Nov	0.030	0.9	4.83	0.73	1.7	3.8
184-L	May	0.436	3.4	1.68	3.08	36.5	3.9
	June	0.294	2.4	4.44	0.44	13.5	3.2
	July	0.159	11.9	5.59	--	16.9	3.3
	Aug	0.082	13.0	5.90	--	14.3	3.4
	Sept	0.076	12.2	5.52	--	9.5	3.4
	Oct	0.043	7.5	3.00	--	4.7	3.6
	Nov	0.040	0.5	3.10	0.30	1.3	3.7

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TABLE A-15. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO DEMONSTRATION PROJECT FOR 1978

Sludge Application	Month	Ortho P	NO_3-N	NH_4-N	Org-N	Cl	pH
mt/ha		mg/1					
0	April	0.037	0.9	1.05	0.08	2.8	3.6
	May	0.029	0.9	1.01	0.10	2.8	3.8
	June	0.013	<0.5	0.87	0.00	1.7	4.2
	July	0.046	0.8	1.59	0.43	2.1	3.8
	Aug	0.036	0.7	1.55	0.53	1.9	3.6
	Sept	0.030	<0.5	2.30	0.38	2.2	2.6
	Oct	0.022	<0.5	2.02	0.19	2.1	4.2
	Nov	0.021	0.7	1.37	0.25	2.0	4.0
	Dec	0.020	<0.5	0.88	0.17	1.9	3.9
7	April	0.029	0.7	0.18	0.31	5.3	6.7
	May	0.020	0.9	0.11	0.23	3.0	7.4
	June	0.012	<0.5	0.11	0.10	1.5	7.4
	July	--	--	--	--	--	--
	Aug	0.045	0.7	0.08	0.22	2.5	7.5
	Sept	0.066	1.0	0.10	--	5.4	7.9
	Oct	0.016	<0.5	0.09	0.29	2.0	8.0
	Nov	0.005	0.9	0.12	0.27	2.5	7.6
	Dec	0.009	<0.5	0.05	0.31	5.4	7.3
11-L	April	0.010	1.1	0.15	0.30	8.1	5.4
	May	0.007	1.3	0.24	0.21	2.4	5.0
	June	0.009	<0.5	0.22	0.21	1.5	5.4
	July	--	<0.5	--	--	1.7	5.0
	Aug	0.013	<0.5	0.14	0.28	4.0	4.7
	Sept	0.008	<0.5	0.15	0.49	1.9	3.8
	Oct	0.014	<0.5	0.18	0.31	2.7	3.6
	Nov	0.003	<0.5	0.13	0.12	2.2	4.2
	Dec	0.003	<0.5	0.12	0.23	5.8	4.3
90	April	0.014	<0.5	0.61	0.12	2.7	4.0
	May	0.021	<0.5	0.47	0.28	1.9	3.9
	June	0.021	<0.5	0.31	0.28	1.6	4.7
	July	0.023	<0.5	0.52	0.24	1.5	3.8
	Aug	0.027	<0.5	0.14	0.26	2.0	3.7
	Sept	0.013	<0.5	0.19	0.29	2.1	3.7
	Oct	0.016	<0.5	<0.05	0.13	1.8	3.8
	Nov	0.012	0.7	<0.05	0.23	2.5	3.9
	Dec	0.007	0.7	<0.05	0.21	1.9	3.8

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TABLE A-15. (Continued)

Sludge Application	Month	Ortho P	NO_3-N	NH_4-N	Org-N	Cl	pH
mt/ha		mg/l					
90-L	April	0.018	<0.5	0.47	0.08	1.8	3.9
	May	0.022	<0.5	0.64	0.07	1.6	3.8
	June	0.023	<0.5	0.34	0.29	1.4	3.7
	July	0.045	<0.5	0.13	0.23	1.5	3.8
	Aug	0.030	<0.5	0.29	0.32	2.0	3.6
	Sept	0.026	<0.5	0.38	0.26	1.9	3.6
	Oct	0.022	<0.5	0.27	0.26	2.4	3.5
	Nov	0.007	<0.5	0.70	0.60	2.1	3.5
	Dec	0.008	<0.5	0.72	0.21	2.8	3.5
184	April	0.023	<0.5	3.05	0.03	2.3	3.8
	May	0.022	0.7	2.33	0.17	2.0	3.8
	June	0.029	<0.5	1.73	1.90	1.4	3.6
	July	0.045	<0.5	2.48	0.48	1.6	3.7
	Aug	0.050	<0.5	1.07	0.60	1.6	3.6
	Sept	0.031	<0.5	1.17	0.60	2.1	3.6
	Oct	0.019	<0.5	0.58	0.23	2.2	3.5
	Nov	0.011	<0.5	0.47	0.31	1.7	3.7
	Dec	0.012	<0.5	0.42	0.14	1.6	3.6
184-L	April	0.018	<0.5	0.73	0.08	1.9	4.0
	May	0.023	<0.5	0.64	0.20	1.4	3.7
	June	0.022	<0.5	0.43	0.20	1.0	3.6
	July	0.031	0.7	0.63	0.47	2.3	3.8
	Aug	0.027	<0.5	0.14	0.28	1.4	3.7
	Sept	0.019	<0.5	0.15	0.41	1.4	3.5
	Oct	0.017	<0.5	0.16	0.23	1.4	3.4
	Nov	0.012	<0.5	0.14	0.23	1.5	3.6
	Dec	0.010	<0.5	<0.05	0.23	1.5	3.6

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TABLE A-16. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO DEMONSTRATION PROJECT FOR 1979

Sludge Application	Month	pH	Cl	NO_3-N	NH_4-N	Org-N	Ortho P
mt/ha		mg/l					
0	March	4.1	1.6	<0.5	0.73	0.08	0.015
	April	4.0	1.7	1.2	0.62	0.14	0.030
	May	4.0	1.6	0.7	0.78	0.41	0.020
	June	3.9	1.5	0.7	0.97	0.23	0.008
	July	3.9	1.8	<0.5	1.23	0.13	0.026
	Aug	3.9	1.8	<0.5	1.71	0.50	0.019
	Sept	4.1	1.5	<0.5	2.00	0.40	0.020
	Oct	3.8	2.6	0.9	1.41	0.20	0.032
7	March	7.5	3.7	0.7	0.07	0.09	0.004
	April	7.5	3.8	<0.5	<0.05	0.15	0.011
	May	7.6	1.8	<0.5	0.08	0.13	0.011
	June	7.6	1.2	<0.5	0.09	0.21	0.016
	July	—	—	—	—	—	—
	Aug	—	—	—	—	—	—
	Sept	—	—	—	—	—	—
	Oct	7.8	5.5	1.5	0.15	0.75	0.011
11-L	March	4.5	3.7	<0.5	0.13	0.10	0.001
	April	4.7	4.7	<0.5	0.10	0.10	0.010
	May	4.6	2.5	<0.5	0.18	0.17	0.023
	June	5.3	1.2	<0.5	0.16	0.15	0.014
	July	3.8	3.7	<0.5	—	—	—
	Aug	3.3	2.4	1.0	0.48	—	0.075
	Sept	—	—	—	—	—	—
	Oct	3.7	7.6	0.8	0.48	0.39	0.157
90-L	March	4.0	2.3	<0.5	0.50	0.34	0.023
	April	3.7	2.8	<0.5	0.47	0.22	0.008
	May	3.6	2.4	<0.5	0.58	0.27	0.014
	June	3.6	2.4	0.7	0.35	0.40	0.011
	July	3.4	3.0	0.8	1.49	0.50	0.042
	Aug	3.2	15.4	1.3	2.14	1.00	0.008
	Sept	3.5	3.3	0.8	2.68	0.60	0.005
	Oct	3.2	5.8	1.6	2.09	0.08	0.018
184-L	March	3.9	3.2	<0.5	0.05	0.11	0.003
	April	3.9	2.1	<0.5	0.07	0.11	0.006
	May	3.7	1.7	<0.5	0.07	0.13	0.022
	June	3.8	1.3	<0.5	0.09	0.15	0.017
	July	3.5	1.0	<0.5	0.09	0.19	0.036
	Aug	3.4	1.1	<0.5	0.11	0.35	0.046
	Sept	3.5	0.9	<0.5	0.27	0.25	0.037
	Oct	3.6	3.4	<0.5	0.10	0.21	0.016

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TABLE A-17. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO DEMONSTRATION PROJECT DURING 1977

Sludge Application	Month	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha				mg/l				
0	May	16.2	55.2	71.2	7.4	529.6	96.6	7.8
	June	65.7	29.6	193.9	2.8	591.4	354.7	5.6
	July	163.9	25.4	35.6	2.8	557.2	267.7	4.2
	Aug	29.1	18.7	28.2	2.3	370.5	63.7	3.8
	Sept	43.9	17.1	32.9	2.7	386.1	137.5	3.7
	Oct	6.9	11.8	18.4	--	--	--	4.8
	Nov	10.7	8.1	16.6	--	--	--	4.0
7	May	0.1	0.6	0.3	3.4	406.1	15.5	10.6
	June	0.1	<0.1	0.3	3.5	577.8	19.3	11.1
	July	0.1	0.4	0.3	3.3	538.7	16.0	10.4
	Aug	0.2	0.5	0.3	2.8	450.5	15.5	8.8
	Sept	0.2	0.1	<0.1	2.8	317.0	35.7	6.1
	Oct	0.3	0.2	0.2	--	--	--	5.3
	Nov	<0.1	<0.1	0.2	--	--	--	4.4
11-L	May	1.6	38.4	27.7	8.3	831.6	261.6	34.1
	June	0.1	25.1	9.7	10.2	770.1	219.6	25.0
	July	1.6	11.9	4.5	10.0	653.6	21.0	19.9
	Aug	0.2	3.6	3.1	6.2	627.0	15.5	9.5
	Sept	0.1	2.1	1.2	3.5	559.8	38.8	5.7
	Oct	0.2	1.1	1.6	--	--	--	4.9
	Nov	<0.1	0.9	1.2	--	--	--	4.3
90	May	1.1	27.9	26.7	8.9	636.8	258.0	13.7
	June	48.2	75.8	77.1	6.4	659.3	487.5	11.0
	July	7.9	37.9	46.1	7.6	646.1	204.7	9.0
	Aug	3.6	23.8	27.4	7.8	598.9	56.2	6.0
	Sept	3.4	18.0	19.2	6.1	461.3	94.9	4.4
	Oct	1.1	12.9	23.4	--	--	--	2.8
	Nov	0.8	11.0	21.5	--	--	--	2.0
90-L	May	35.9	28.2	29.6	13.5	565.4	205.5	17.0
	June	6.9	205.6	228.6	2.0	647.5	624.5	8.5
	July	6.9	114.5	220.4	1.4	668.3	528.2	8.4
	Aug	1.7	18.0	41.9	2.2	726.4	136.9	5.5
	Sept	1.1	10.0	23.8	2.1	697.2	109.7	3.2
	Oct	0.5	4.9	24.9	--	--	--	2.0
	Nov	0.4	4.3	22.0	--	--	--	1.3

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TABLE A-17. (Continued)

Sludge Application	Month	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha		mg/l						
184	May	3.4	38.9	44.7	6.9	712.7	241.8	10.3
	June	0.7	50.4	48.3	6.7	673.4	188.0	9.9
	July	1.2	33.5	39.3	6.7	592.3	96.0	8.1
	Aug	0.7	30.5	27.8	8.2	455.3	78.3	6.3
	Sept	0.5	20.3	19.4	6.9	319.5	83.7	4.6
	Oct	0.3	15.0	20.9	--	--	--	2.6
	Nov	0.2	13.0	17.4	--	--	--	1.2
184-L	May	9.7	69.5	162.9	7.4	577.3	504.2	14.4
	June	1.9	68.1	181.3	3.0	585.4	466.9	9.7
	July	5.2	52.5	123.4	4.2	632.4	341.7	9.7
	Aug	0.8	30.0	52.1	5.3	586.8	110.7	8.0
	Sept	0.7	27.7	33.7	5.3	536.9	111.2	5.0
	Oct	0.3	10.2	35.6	--	--	--	2.8
	Nov	0.3	8.7	31.7	--	--	--	1.7

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TABLE A-18. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO COUNTY DEMONSTRATION PROJECT DURING 1978

Sludge Application	Month	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha					mg/l			
0	April	85.8	4.9	63.2	2.6	203.2	68.9	2.8
	May	11.1	4.6	36.6	1.4	298.6	85.3	2.7
	June	5.9	3.6	17.9	3.0	297.9	75.0	3.4
	July	18.1	3.0	31.9	1.9	205.4	71.7	3.1
	Aug	53.0	3.9	59.3	2.2	255.1	94.8	3.4
	Sept	42.6	5.1	71.9	2.9	302.7	125.0	3.7
	Oct	30.1	3.8	59.8	2.0	268.9	104.3	3.3
	Nov	59.4	5.0	114.3	1.4	299.1	124.6	3.4
	Dec	3.2	1.8	26.2	1.1	212.7	68.6	3.0
7	April	0.3	0.6	2.0	2.7	307.4	20.2	4.2
	May	0.1	0.7	0.6	3.5	300.4	23.1	2.7
	June	0.6	0.9	1.6	1.3	254.6	16.2	2.5
	July	--	--	--	--	--	--	--
	Aug	27.6	1.8	2.1	2.5	304.2	17.0	4.7
	Sept	17.4	7.0	37.8	4.0	383.0	42.1	6.9
	Oct	7.4	2.5	8.0	2.3	371.2	29.9	5.2
	Nov	0.3	2.1	4.6	2.2	338.1	24.0	4.9
	Dec	0.1	1.4	2.1	2.3	243.9	18.9	3.5
11-L	April	0.1	<0.1	<0.1	3.6	219.7	26.0	3.7
	May	0.1	<0.1	<0.1	1.8	216.5	28.6	3.9
	June	0.6	0.1	<0.1	1.2	199.2	23.6	2.9
	July	--	--	--	--	--	--	--
	Aug	0.3	0.3	0.1	0.8	217.6	24.0	2.1
	Sept	0.1	<0.1	<0.1	1.5	264.0	25.5	2.3
	Oct	<0.1	<0.1	0.1	0.5	231.6	27.4	2.4
	Nov	0.1	0.1	0.1	0.5	238.2	29.9	4.0
	Dec	0.1	0.1	0.2	0.4	185.1	22.0	3.4
90	April	0.3	3.9	7.0	3.7	176.6	31.7	2.3
	May	0.6	4.9	11.7	1.7	176.2	33.0	1.7
	June	0.2	3.5	7.9	1.4	160.6	23.2	1.3
	July	0.6	4.3	13.5	2.4	146.6	23.6	2.6
	Aug	0.1	3.9	9.8	2.1	135.4	28.8	2.4
	Sept	0.2	4.4	10.8	2.4	137.7	31.1	2.9
	Oct	0.1	4.5	12.2	2.6	119.7	28.2	1.9
	Nov	0.2	4.7	12.4	1.8	116.6	28.0	2.0
	Dec	0.3	4.7	12.5	1.7	105.7	24.0	2.1

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TABLE A-18. (Continued)

Sludge Application	Month	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha					mg/1			
90-L	April	0.4	4.3	7.0	3.1	546.1	43.5	2.4
	May	0.2	2.5	8.1	0.7	291.9	31.2	0.9
	June	0.1	2.3	5.4	0.6	366.0	32.1	1.6
	July	0.4	2.3	12.9	1.2	573.3	40.5	4.3
	Aug	0.5	4.3	13.8	1.8	434.7	45.2	3.7
	Sept	0.4	6.7	17.9	1.9	441.0	54.6	3.6
	Oct	0.4	3.9	14.8	4.2	391.0	50.8	3.2
	Nov	100.5	13.3	85.2	0.7	372.6	108.7	3.0
	Dec	61.4	11.4	73.5	0.6	365.0	69.1	2.4
184	April	0.3	4.5	11.9	2.2	171.7	25.7	1.7
	May	0.3	10.7	22.5	2.7	177.1	39.0	1.4
	June	0.1	3.1	6.4	2.6	107.0	17.3	1.0
	July	0.2	6.6	19.8	2.3	125.7	29.9	1.6
	Aug	0.2	3.2	9.3	1.9	95.7	17.0	1.9
	Sept	0.2	3.8	12.9	2.1	116.7	21.3	1.9
	Oct	0.2	5.0	14.8	2.1	110.0	23.2	1.3
	Nov	0.3	7.2	22.5	1.5	137.6	32.8	1.7
	Dec	0.2	7.5	25.3	0.8	161.8	40.6	2.0
184-L	April	1.1	3.2	14.0	7.8	226.5	24.4	2.2
	May	0.4	2.3	15.9	1.4	209.1	18.3	1.6
	June	0.1	1.6	9.8	0.8	168.9	13.2	1.2
	July	3.4	1.8	15.7	1.0	161.6	12.1	2.4
	Aug	16.3	2.6	15.0	1.2	157.9	17.4	3.5
	Sept	51.0	3.5	22.8	1.2	175.2	22.2	3.0
	Oct	23.3	2.8	17.8	1.2	160.8	17.8	3.7
	Nov	2.7	2.7	15.7	0.8	145.1	17.4	2.5
	Dec	0.3	2.3	12.5	0.7	137.6	15.2	2.3

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TABLE A-19. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO DEMONSTRATION PROJECT FOR 1979

Sludge Application	Month	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha		mg/l						
0	March	16.8	2.3	36.2	1.0	194.8	70.7	2.9
	April	18.2	1.4	20.7	1.1	188.0	53.4	1.8
	May	16.4	1.5	21.7	1.1	188.5	42.2	2.0
	June	12.4	1.3	18.7	1.3	154.6	42.5	3.1
	July	10.7	1.5	23.5	1.9	156.9	50.0	2.3
7	March	<0.1	<0.1	<0.1	0.5	115.3	13.8	3.4
	April	0.2	0.1	<0.1	1.1	120.9	12.4	2.4
	May	<0.1	<0.1	<0.1	0.5	156.7	18.4	3.4
	June	0.4	0.1	<0.1	0.4	144.0	16.5	1.8
	July	--	--	--	--	--	--	--
11-L	March	0.1	0.7	1.4	1.5	145.8	10.8	3.6
	April	0.1	0.4	1.3	2.1	163.3	11.4	2.6
	May	0.1	0.5	1.2	2.4	188.0	14.3	3.1
	June	0.2	0.5	1.6	2.7	248.3	17.8	3.2
	July	--	--	--	--	--	--	--
90-L	March	1.0	1.3	5.2	0.8	75.7	7.9	2.0
	April	0.9	0.9	4.4	2.2	71.4	6.1	1.0
	May	1.5	0.9	4.1	1.1	56.0	6.3	1.3
	June	2.1	1.0	5.0	1.4	72.9	6.9	2.7
	July	12.5	1.3	6.5	2.1	76.1	8.8	1.5
184-L	March	25.5	8.2	44.6	0.9	302.1	39.0	2.2
	April	32.3	7.2	32.2	1.3	311.7	36.0	1.6
	May	34.0	6.2	27.4	1.3	305.9	38.2	1.7
	June	47.7	5.4	23.1	1.3	316.5	34.7	1.7
	July	30.7	7.9	47.8	2.1	303.0	49.4	2.0

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TABLE A-20. SOIL PERCOLATE WATER ANALYSES FOR TRACE METALS AT THE VENANGO DEMONSTRATION PROJECT DURING 1977

Sludge Application	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha					mg/l			
0	May	1.98	7.44	0.75	0.18	1.95	0.006	4.09
	June	1.00	3.71	0.36	0.07	0.90	0.005	1.98
	July	0.86	3.37	0.32	0.07	0.75	0.006	1.53
	Aug	0.20	1.18	0.06	0.05	0.36	0.004	0.62
	Sept	0.20	1.33	0.08	0.08	0.32	0.005	0.63
	Oct	0.08	0.86	<0.01	0.01	0.23	0.004	0.37
	Nov	0.10	1.37	<0.01	0.06	0.18	0.004	0.38
7	May	0.01	0.10	<0.01	0.05	<0.01	<0.001	<0.01
	June	<0.01	0.22	<0.01	0.05	0.01	<0.001	<0.01
	July	0.01	0.17	<0.01	0.05	0.01	<0.001	<0.01
	Aug	0.01	0.08	<0.01	0.05	0.01	<0.001	<0.01
	Sept	0.01	0.37	0.01	0.05	<0.01	0.001	0.04
	Oct	<0.01	0.03	<0.01	<0.01	0.01	<0.001	0.02
	Nov	0.01	0.06	<0.01	0.01	<0.01	<0.001	0.02
11-L	May	0.16	3.87	0.05	0.06	1.46	0.009	2.58
	June	0.03	2.05	0.04	0.05	0.71	0.006	1.43
	July	0.03	2.60	<0.01	0.05	0.35	0.001	0.69
	Aug	0.04	0.38	<0.01	0.06	0.06	<0.001	0.11
	Sept	0.02	0.25	0.02	0.07	0.02	0.001	0.08
	Oct	<0.01	0.08	<0.01	0.01	0.02	<0.001	0.04
	Nov	0.01	0.22	<0.01	0.03	<0.01	<0.001	0.03
90	May	0.01	2.70	0.03	0.05	0.95	0.006	1.67
	June	0.46	9.12	0.05	0.05	2.39	0.021	4.51
	July	0.29	6.08	0.03	0.07	1.19	0.007	2.33
	Aug	0.21	3.44	0.03	0.05	0.82	0.006	1.40
	Sept	0.13	2.75	0.02	0.07	0.65	0.007	1.00
	Oct	0.12	2.41	<0.01	0.02	0.57	0.009	0.94
	Nov	0.09	2.37	<0.01	0.01	0.49	0.005	0.78
90-L	May	0.77	13.55	0.25	0.17	6.17	0.037	8.24
	June	1.84	11.72	0.21	0.07	6.44	0.024	9.21
	July	1.02	13.10	0.20	0.12	5.40	0.021	7.54
	Aug	0.14	2.79	0.05	0.05	0.64	0.005	1.10
	Sept	0.07	2.54	0.04	0.07	0.37	0.004	0.59
	Oct	0.05	1.16	0.01	0.05	0.18	0.003	0.35
	Nov	0.03	1.07	<0.05	0.07	0.14	0.002	0.23

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TABLE A-20. (Continued)

Sludge Application	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha		mg/l						
184	May	0.14	2.37	<0.01	0.05	1.07	0.008	1.72
	June	0.18	2.39	0.02	0.05	1.32	0.026	2.30
	July	0.16	3.74	0.02	0.05	0.87	0.009	1.53
	Aug	0.12	2.01	<0.01	0.05	0.76	0.005	1.26
	Sept	0.08	1.74	0.01	0.05	0.55	0.006	0.87
	Oct	0.05	1.32	<0.01	<0.01	0.42	0.006	0.69
	Nov	0.04	1.17	<0.01	<0.01	0.33	0.006	0.52
184-L	May	0.33	8.78	0.06	0.09	2.62	0.019	4.92
	June	0.45	9.55	0.07	0.05	2.53	0.015	5.31
	July	0.39	9.99	0.07	0.05	2.15	0.018	3.96
	Aug	0.23	4.61	0.02	0.07	1.30	0.005	2.38
	Sept	0.13	3.77	0.01	0.07	0.91	0.006	1.44
	Oct	0.09	2.31	<0.01	0.02	0.56	0.008	1.02
	Nov	0.06	2.33	0.01	0.03	0.41	0.006	0.74

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TABLE A-21. SOIL PERCOLATE WATER ANALYSES FOR TRACE METALS AT THE VENANGO DEMONSTRATION PROJECT DURING 1978

Sludge Application	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha		- - - - - - - - - - - - -			mg/1	- - - - - - - - - - - - -		
0	April	0.27	1.03	0.05	0.07	0.32	0.002	0.43
	May	0.11	0.62	0.03	0.06	0.22	0.002	0.26
	June	0.07	0.82	0.02	0.07	0.20	0.002	0.26
	July	0.11	1.04	0.01	0.14	0.16	0.002	0.27
	Aug	0.17	1.83	0.07	0.15	0.17	0.001	0.33
	Sept	0.17	2.73	0.09	0.12	0.32	0.002	0.38
	Oct	0.14	0.87	0.06	0.09	0.30	0.001	0.34
	Nov	0.15	1.11	0.07	0.13	0.21	0.002	0.50
	Dec	0.03	0.73	0.02	0.08	0.09	0.001	0.19
7	April	0.01	1.55	0.01	0.02	0.15	0.001	0.11
	May	0.01	0.45	<0.01	0.04	0.10	<0.001	0.12
	June	<0.01	0.14	<0.01	0.10	0.11	<0.001	0.21
	July	--	--	--	--	--	--	--
	Aug	0.01	0.56	<0.01	0.15	0.04	<0.001	0.11
	Sept	0.29	2.93	0.03	0.17	0.33	<0.001	0.39
	Oct	0.05	0.77	0.02	0.09	0.24	0.001	0.18
	Nov	0.01	0.31	0.02	0.08	0.11	0.001	0.13
	Dec	<0.01	0.15	0.01	0.07	0.10	0.001	0.08
11-L	April	<0.01	0.67	<0.01	0.08	0.13	<0.001	0.11
	May	0.01	0.57	<0.01	0.11	0.11	<0.001	0.12
	June	<0.01	0.11	<0.01	<0.01	0.10	<0.001	0.14
	July	--	--	--	--	--	--	--
	Aug	0.01	0.58	<0.01	0.16	<0.01	<0.001	0.05
	Sept	0.01	0.41	<0.01	0.14	<0.01	<0.001	0.01
	Oct	0.01	0.11	<0.01	0.09	0.05	<0.001	0.01
	Nov	0.01	0.18	0.02	0.07	0.02	<0.001	0.01
	Dec	0.01	0.09	0.01	0.05	0.02	<0.001	0.01
90	April	0.04	1.66	<0.01	0.09	0.19	0.003	0.28
	May	0.06	1.90	<0.01	0.17	0.18	0.003	0.25
	June	0.05	1.09	<0.01	<0.01	0.23	0.003	0.26
	July	0.08	1.52	<0.01	0.11	0.15	0.004	0.29
	Aug	0.07	1.42	<0.01	0.12	0.19	0.004	0.30
	Sept	0.06	2.16	<0.01	0.11	0.16	0.004	0.22
	Oct	0.06	1.18	<0.01	0.11	0.25	0.004	0.26
	Nov	0.04	1.21	<0.01	0.06	0.16	0.004	0.27
	Dec	0.04	1.23	<0.01	0.10	0.17	0.003	0.27

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TABLE A-21. (Continued)

Sludge Application	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha		mg/l						
90-L	April	<0.01	1.02	<0.01	0.12	0.19	0.003	0.25
	May	0.02	0.50	<0.01	0.08	0.10	0.001	0.16
	June	0.02	0.68	<0.01	<0.01	0.11	0.001	0.21
	July	0.06	1.79	<0.01	0.18	0.14	0.001	0.20
	Aug	0.04	0.88	<0.01	0.17	0.16	0.001	0.28
	Sept	0.04	0.96	<0.01	0.14	0.23	0.001	0.29
	Oct	0.03	0.86	0.02	0.10	0.28	0.001	0.26
	Nov	0.11	1.69	0.02	0.12	0.44	0.004	0.83
	Dec	0.10	1.77	0.02	0.13	0.45	0.004	0.81
184	April	0.02	0.95	<0.01	0.14	0.26	0.002	0.33
	May	0.05	1.82	<0.01	0.11	0.30	0.005	0.37
	June	0.01	0.71	<0.01	<0.01	0.13	0.002	0.22
	July	0.07	1.10	<0.01	0.11	0.25	0.005	0.31
	Aug	0.03	1.04	<0.01	0.11	0.09	0.002	0.22
	Sept	0.03	1.26	<0.01	0.10	0.16	0.003	0.23
	Oct	0.03	0.98	<0.01	0.09	0.29	0.003	0.21
	Nov	0.03	1.04	0.01	0.07	0.18	0.004	0.32
	Dec	0.03	1.41	0.01	0.05	0.24	0.005	0.41
184-L	April	0.03	1.82	<0.01	<0.01	0.27	0.002	0.27
	May	0.03	1.31	<0.01	<0.01	0.18	0.001	0.25
	June	0.02	0.71	<0.01	0.08	0.14	0.001	0.26
	July	0.06	1.28	<0.01	0.12	0.13	0.001	0.22
	Aug	0.06	1.42	<0.01	0.13	0.18	0.002	0.32
	Sept	0.09	1.18	<0.01	0.12	0.24	0.002	0.36
	Oct	0.06	1.21	<0.01	0.10	0.27	0.002	0.27
	Nov	0.02	0.75	<0.01	0.07	0.14	0.002	0.22
	Dec	0.01	0.76	<0.01	0.04	0.13	0.001	0.21

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TABLE A-22. SOIL PERCOLATE WATER ANALYSES FOR TRACE METALS AT THE VENANGO COUNTY DEMONSTRATION PROJECT DURING 1979

Sludge Application	Month	Cu	Zn	Cr	Pb	Co	Cd	Ni
mt/ha		mg/l						
0	Mar	0.08	0.37	0.04	0.06	0.09	<0.001	0.21
	Apr	0.06	0.35	0.02	0.04	0.10	<0.001	0.20
	May	0.06	0.31	0.02	0.05	0.07	<0.001	0.15
	June	0.05	0.35	0.03	0.03	0.06	<0.001	0.11
	July	0.06	0.47	0.03	0.04	0.09	<0.001	0.12
7	Mar	0.01	0.04	0.01	0.02	0.03	<0.001	0.02
	Apr	0.01	0.15	<0.01	0.01	0.04	<0.001	0.01
	May	<0.01	0.03	<0.01	0.03	0.01	<0.001	<0.01
	June	<0.01	0.10	0.01	0.03	<0.01	<0.001	<0.01
	July	--	--	--	--	--	--	--
11-L	Mar	0.01	0.15	0.01	0.02	0.04	<0.001	0.09
	Apr	0.01	1.10	<0.01	0.03	0.08	0.001	0.05
	May	<0.01	0.28	<0.01	0.03	0.02	<0.001	0.06
	June	<0.01	0.26	0.02	0.11	0.03	<0.001	0.06
	July	--	--	--	--	--	--	--
90-L	Mar	0.02	0.42	0.01	0.01	0.07	0.001	0.13
	Apr	0.01	1.31	<0.01	0.05	0.10	<0.001	0.08
	May	<0.01	0.20	<0.01	0.03	0.06	<0.001	0.07
	June	0.02	0.43	<0.01	0.04	0.06	0.001	0.08
	July	0.03	0.54	<0.01	<0.01	0.11	0.001	0.13
184-L	Mar	0.09	0.80	0.02	0.06	0.27	0.001	0.53
	Apr	0.08	1.17	0.02	0.08	0.27	0.001	0.41
	May	0.06	0.69	0.02	0.01	0.22	0.001	0.32
	June	0.04	0.66	0.01	0.07	0.16	0.002	0.30
	July	0.15	1.33	0.04	0.06	0.36	0.001	0.48

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TABLE A-23. GROUNDWATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENT AT THE VENANGO DEMONSTRATION SITE FOR 1977

Well No.	Month	Fe	Mn	Al	K	Ca	Mg	Na
		- - - - - - - - -	- - - -	- - - mg/l	- - -	- - - -	- - - -	- - -
Well 1 (Control)	July	677	122	14	7	575	488	16
	Aug	673	109	11	7	578	502	16
	Sept	652	95	9	7	485	359	15
	Oct	718	102	14	--	--	--	16
	Nov	610	104	5	--	--	--	15
Well 2 (Dewatered Sludge)	July	433	101	5	5	589	288	9
	Aug	532	105	5	6	593	315	9
	Sept	401	80	4	6	528	271	8
	Oct	383	95	12	--	--	--	9
	Nov	339	73	5	--	--	--	9
Well 3 (Liquid Sludge)	July	67	22	2	1	523	40	12
	Aug	50	20	1	1	523	35	12
	Sept	25	20	1	2	463	103	11
	Oct	59	18	1	--	--	--	12
	Nov	53	18	<1	--	--	--	12

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TABLE A-24. GROUNDWATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO COUNTY DEMONSTRATION SITE FOR 1978

Well No.	Month	Fe	Mn	Al	K	Ca	Mg	Na
		- - - - - - - - -	- - -	- - -	mg/l	- - -	- - -	- - -
Well 1 (Control)	March	34	10	<1	1	236	54	6
	April	1034	119	5	8	424	225	15
	May	947	115	4	8	401	166	14
	June	913	109	5	8	407	181	14
	July	1328	105	5	8	459	360	14
	Aug	1141	88	11	8	391	322	16
	Sept	1167	96	9	19	436	328	15
	Oct	1141	93	14	7	413	322	15
	Nov	438	55	1	9	275	107	8
	Dec	749	1	9	8	435	185	16
Well 2 (Dewatered Sludge)	April	468	96	6	6	463	173	9
	May	466	88	3	6	343	143	9
	June	440	84	47	6	690	239	7
	July	472	65	4	6	405	215	7
	Aug	534	70	9	7	322	191	8
	Sept	581	76	8	7	322	184	9
	Oct	472	70	7	7	368	203	8
	Nov	484	87	7	7	459	238	8
	Dec	375	76	7	6	455	165	8
Well 3 (Liquid Sludge)	March	975	124	2	8	440	307	15
	April	81	23	<1	1	370	94	12
	May	65	22	<1	1	353	91	11
	June	75	21	<1	1	353	92	10
	July	122	17	<1	1	395	99	13
	Aug	73	19	<1	1	384	94	14
	Sept	125	16	<1	1	400	90	14
	Oct	165	16	<1	1	382	90	15
	Nov	71	17	1	1	346	87	16
	Dec	134	19	1	2	364	88	18

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Table A-25. GROUNDWATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO COUNTY DEMONSTRATION SITE FOR 1979

Well No.	Month	Fe	Mn	Al	K	Ca	Mg	Na
		mg/l						
Well 1 (Control)	March	793	105	3	8	462	344	14
	April	810	98	4	8	289	203	13
	May	750	99	4	9	450	215	13
	June	722	99	4	8	445	191	12
	July	725	100	4	8	446	239	13
Well 2 (Dewatered Sludge)	March	375	74	8	6	455	187	8
	April	388	70	4	6	348	132	8
	May	348	68	3	6	405	160	8
	June	360	65	4	6	432	165	6
	July	363	62	4	7	471	129	11
Well 3 (Liquid Sludge)	March	213	15	<1	2	354	61	15
	April	191	14	<1	2	325	48	14
	May	168	13	<1	2	308	90	13
	June	97	5	<1	2	251	92	14
	July	36	2	<1	2	181	92	14

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TABLE A-26. LAKE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO DEMONSTRATION PROJECT DURING 1977

Lake No. and Month	Fe	Mn	Cr	Co	Pb	Ni	Al	K	Ca	Mg	Na
	- - - -	- - - -	- - - -	- - - -	- - - -	mg/l	- - - -	- - - -	- - - -	- - - -	- - - -
Lake 1											
June	1.20	8.72	<0.01	0.05	0.11	0.19	4.5	2.8	172.2	15.5	33.1
July	1.40	9.51	<0.01	0.05	0.14	0.28	2.2	2.9	162.8	15.5	33.1
Aug	0.72	10.04	<0.01	0.05	0.18	0.25	2.2	2.7	144.3	15.5	28.3
Sept	0.65	8.51	<0.01	0.02	0.14	0.26	2.0	3.3	170.9	44.3	25.0
Oct	0.24	8.32	0.02	<0.01	0.16	0.23	2.4	--	--	--	22.8
Nov	0.15	7.53	<0.01	<0.01	0.13	0.17	2.4	--	--	--	22.8
Lake 2											
June	0.18	<0.01	<0.01	0.05	<0.01	<0.01	0.3	2.3	158.1	15.5	1.6
July	0.09	0.42	<0.01	0.05	<0.01	0.01	0.3	2.0	107.4	15.5	1.9
Aug	0.19	0.42	<0.01	0.05	0.06	0.08	0.3	1.7	95.1	15.5	1.5
Sept	0.24	0.04	<0.01	0.03	<0.01	0.07	<0.1	2.2	108.7	19.2	1.2
Oct	0.25	0.07	<0.01	0.07	0.01	0.04	0.2	--	--	--	1.5
Nov	0.32	0.04	<0.01	<0.01	<0.01	0.02	0.2	--	--	--	1.1

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Table A-27. LAKE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO DEMONSTRATION PROJECT DURING 1978.

Lake No. and Month	Fe	Mn	Cr	Co	Pb	Ni	Al	K	Ca	Mg	Na
	mg/1										
Lake 1											
April	1.37	4.69	<0.01	0.05	0.11	0.23	0.4	1.9	112.2	27.4	24.6
May	1.30	5.10	<0.01	0.12	0.06	0.08	1.6	2.4	137.9	32.0	28.1
June	0.35	5.86	<0.01	<0.01	0.21	0.19	2.1	2.1	126.8	34.0	24.9
July	0.36	6.19	<0.01	0.09	0.14	0.23	3.4	2.0	95.8	34.7	27.9
Aug	0.53	6.47	<0.01	0.18	0.29	0.28	4.1	2.6	102.5	36.0	25.6
Sept	1.14	8.19	<0.01	0.09	0.21	0.23	6.0	13.7	136.1	42.4	29.4
Oct	0.44	7.90	<0.01	0.11	0.30	0.25	5.3	2.1	113.7	41.1	24.2
Nov	0.37	8.9	<0.01	0.09	0.19	0.28	5.1	2.1	113.2	40.8	23.2
Dec	0.30	0.09	<0.01	0.07	<0.01	0.01	0.4	1.7	78.1	15.9	1.4
Lake 2											
April	2.04	2.27	<0.01	0.09	0.07	0.17	<0.1	1.7	109.1	18.8	1.6
May	0.10	0.77	<0.01	0.13	0.03	0.01	<0.1	1.7	109.1	19.6	0.9
June	0.32	0.39	<0.01	<0.01	0.09	0.09	<0.1	1.8	124.0	23.2	0.9
July	0.14	0.04	<0.01	0.09	<0.01	0.01	<0.1	2.0	104.8	19.1	1.4
Aug	0.32	0.04	<0.01	0.11	0.15	0.04	<0.1	2.0	118.2	18.4	2.2
Sept	0.40	0.13	<0.01	0.09	<0.01	0.01	<0.1	2.5	93.5	18.4	1.6
Oct	0.32	0.01	<0.01	0.09	<0.01	0.01	<0.1	1.8	84.5	16.6	1.3
Nov	0.16	0.09	<0.01	0.06	<0.01	0.01	0.1	1.8	80.6	16.5	1.3
Dec	0.19	0.05	<0.01	0.07	<0.01	<0.01	0.1	1.8	78.1	15.9	1.3

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Table A-28. LAKE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE VENANGO DEMONSTRATION PROJECT DURING 1979

Lake No. and Month	Fe	Mn	Cr	Co	Pb	Ni	Al	K	Ca	Mg	Na
						mg/1					
Lake 1											
March	0.17	2.79	0.02	<0.01	0.07	0.09	0.9	1.1	34.6	10.7	16.5
April	0.44	4.70	<0.01	0.01	0.09	0.12	1.7	1.5	65.2	21.0	20.7
May	0.30	4.86	<0.01	<0.01	0.14	0.16	1.6	1.5	61.5	20.0	22.4
June	0.31	5.20	<0.01	0.01	0.10	0.16	1.8	1.4	67.3	25.3	23.7
July	0.47	6.59	<0.01	0.02	0.16	0.16	2.7	1.6	80.7	31.5	22.5
Aug	1.05	7.45	<0.01	0.02	0.16	0.21	3.7	2.1	85.7	35.6	19.5
Sept	1.24	9.57	0.02	0.04	0.24	0.21	4.8	2.3	147.0	40.8	21.9
Oct	0.64	9.01	<0.01	0.01	0.11	0.19	3.9	2.0	95.2	30.4	15.6
Lake 2											
March	0.18	0.25	0.01	<0.01	<0.01	0.02	0.2	1.6	58.9	11.3	2.3
April	1.69	0.74	<0.01	0.01	0.01	<0.01	0.4	1.7	83.7	14.0	1.2
May	0.63	0.63	<0.01	<0.01	0.05	0.02	0.1	1.7	71.0	14.7	1.2
June	0.17	0.19	<0.01	<0.01	0.09	<0.01	0.1	1.6	70.9	16.0	2.1
July	0.06	0.07	0.01	<0.01	<0.01	0.01	<0.1	1.3	81.4	17.5	1.1
Aug	0.43	0.06	<0.01	0.04	0.02	0.02	0.4	1.4	85.6	16.3	1.5
Sept	0.02	<0.01	<0.01	0.06	0.02	0.02	0.2	1.3	81.4	14.6	1.1
Oct	0.09	0.01	<0.01	<0.01	0.02	0.02	0.1	1.4	74.7	13.3	1.0

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TABLE A-29. ANALYSES OF LACKAWANNA COUNTY REFUSE SAMPLES, TAKEN PRIOR TO SLUDGE APPLICATION, FOR pH, KJELDAHL NITROGEN, TOTAL SULFUR, AND BRAY PHOSPHORUS

Sludge Application	Refuse Depth	pH	Kjeldahl Nitrogen	Total Sulfur	Bray Phosphorus
mt/ha	cm		%	%	μg/g
0	0 - 15	4.0	0.18	0.55	4.25
	15 - 30	3.9	0.10	0.98	8.00
	30 - 60	3.8	0.18	0.73	9.25
	60 - 90	3.9	0.12	0.79	13.75
80	0 - 15	3.8	0.22	0.30	15.75
	15 - 30	3.9	0.12	0.35	14.50
	30 - 60	3.8	0.12	0.55	9.00
	60 - 90	4.0	0.29	0.45	12.25
108	0 - 15	3.6	0.41	0.57	7.75
	15 - 30	3.7	0.25	0.50	9.50
	30 - 60	3.8	0.22	0.53	15.75
	60 - 90	3.9	0.26	0.52	9.75

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TABLE A-30. MEAN CONCENTRATIONS OF SELECTED CONSTITUENTS IN THE REFUSE AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT PRIOR TO SLUDGE APPLICATION

Sludge Application	Depth	Fe	Mn	Al	K	Ca	Mg
mt/ha	cm	- - - - - - - - - - - -	- - - -	-μg/g - - -	- - - -	- - - -	- - - -
0	0 - 15	33.2	14.2	181.5	31.2	240.0	18.0
	15 - 30	27.7	12.3	156.0	39.0	240.0	30.0
	30 - 60	25.8	10.3	156.0	39.0	240.0	21.6
	60 - 90	28.3	7.8	182.0	35.1	240.0	24.0
80	0 - 15	27.0	4.0	164.5	31.2	256.0	15.6
	15 - 30	26.5	4.5	178.5	31.2	266.0	21.6
	30 - 60	28.0	5.0	181.0	39.0	296.0	24.0
	60 - 90	29.5	5.0	183.0	39.0	270.0	36.0
108	0 - 15	31.5	7.0	145.0	27.3	470.0	45.6
	15 - 30	29.0	7.0	138.5	27.3	446.0	48.0
	30 - 60	26.5	6.5	138.5	27.3	470.0	36.0
	60 - 90	25.5	9.5	129.5	35.1	380.0	30.0

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TABLE A-31. MEAN CONCENTRATIONS OF EXTRACTABLE TRACE METALS IN THE REFUSE AT THE LACKAWANNA COUNTY DEMONSTRATION PROJECT PRIOR TO SLUDGE APPLICATION

Sludge Application	Depth	Cu	Zn	Cr	Pb	Co	Ni	Cd
mt/ha	cm				-µg/g			
0	0 - 15	8.45	4.13	0.04	1.46	1.31	1.28	0.013
	15 - 30	8.76	3.99	0.01	1.03	1.28	1.14	0.011
	30 - 60	9.14	3.74	0.03	1.28	1.15	1.00	0.011
	60 - 90	8.19	2.93	0.04	0.70	0.89	0.64	0.011
80	0 - 15	7.13	1.13	<0.01	3.50	<0.01	0.25	0.005
	15 - 30	6.88	1.50	<0.01	1.75	<0.01	0.25	0.004
	30 - 60	6.75	1.25	<0.01	1.25	<0.01	0.13	0.004
	60 - 90	7.50	1.38	<0.01	0.75	<0.01	0.50	0.005
108	0 - 15	7.63	1.50	<0.01	1.13	0.38	0.50	0.009
	15 - 30	7.63	1.75	<0.01	0.88	0.38	0.63	0.009
	30 - 60	7.75	1.75	<0.01	1.00	0.25	0.38	0.006
	60 - 90	8.25	2.13	<0.01	0.75	0.38	0.63	0.009

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TABLE A-32. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE LACKAWANNA DEMONSTRATION PROJECT DURING 1978

Sludge Application	Month	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha					mg/l			
0	May	0.3	9.6	23.7	9.4	294.6	42.5	7.4
	June	0.2	9.9	26.7	4.4	304.4	48.7	8.1
	July	0.1	9.5	36.2	5.5	274.1	55.8	10.2
	Aug	0.7	8.6	39.1	5.9	306.9	60.5	10.7
	Sept	0.2	7.7	39.7	4.8	310.2	59.6	8.1
	Oct	0.4	6.6	38.6	3.2	306.5	66.5	5.1
	Nov	0.4	6.6	44.8	2.7	309.9	68.1	5.4
	Dec	0.7	6.7	46.9	2.3	308.5	71.6	5.1
80	May	0.3	0.7	3.1	2.3	31.5	5.2	2.3
	June	0.1	0.6	4.0	2.6	29.4	5.3	2.2
	July	0.1	0.6	5.0	2.8	23.0	5.5	2.6
	Aug	0.1	0.7	5.3	2.9	30.8	6.6	2.7
	Sept	0.2	0.7	5.1	3.7	22.6	7.0	2.1
	Oct	0.2	0.9	9.0	2.5	51.9	10.0	2.3
	Nov	0.1	0.9	13.2	2.3	28.2	11.3	2.3
	Dec	0.1	1.0	11.3	1.8	25.5	9.7	1.9
108	May	0.1	1.4	5.9	4.1	36.2	6.3	2.7
	June	0.1	1.9	12.0	5.2	81.3	21.0	3.9
	July	0.1	2.0	13.5	6.0	78.6	22.1	4.4
	Aug	0.2	2.1	15.8	5.6	84.0	23.5	4.3
	Sept	0.4	2.5	19.2	4.7	114.9	25.4	3.9
	Oct	0.2	2.2	17.0	2.6	91.7	23.0	3.4
	Nov	0.1	2.5	19.0	2.4	88.5	23.5	3.2
	Dec	0.1	2.6	20.3	2.2	89.1	24.9	3.3

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TABLE A-33. SOIL PERCOLATE WATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE LACKAWANNA DEMONSTRATION PROJECT DURING 1979

Sludge Application	Month	Fe	Mn	Al	K	Ca	Mg	Na
mt/ha		- - - - - - -	- - - -	- - - -	mg/l	- - - -	- - - -	- - - -
0	March	0.1	0.9	6.6	0.8	73.1	17.4	2.7
	April	0.1	1.3	9.3	1.4	60.2	17.5	1.3
	May	0.1	1.1	8.3	1.7	57.3	13.2	1.9
	June	<0.1	0.8	5.2	1.5	42.9	10.9	1.2
	July	<0.1	0.8	4.8	2.1	43.6	11.2	1.8
	Aug	0.4	0.7	5.9	3.2	27.9	8.3	2.7
	Sept	0.1	1.0	7.5	3.8	33.7	9.9	2.9
	Oct	0.3	0.8	7.2	2.9	23.7	8.1	2.2
80	March	<0.1	0.4	5.8	1.3	17.2	4.5	2.4
	April	0.1	0.4	6.2	1.5	11.8	4.2	1.2
	May	<0.1	0.4	6.2	2.2	13.8	5.0	1.9
	June	0.1	0.4	5.4	2.1	11.5	4.3	1.5
	July	0.1	0.5	7.8	2.9	17.5	6.6	2.1
	Aug	0.1	1.1	5.3	1.7	55.3	10.6	1.8
	Sept	0.1	1.5	9.9	2.6	71.2	16.7	2.0
	Oct	<0.1	1.1	5.8	1.2	49.2	9.5	1.6
108	March	0.2	5.1	49.6	1.8	258.1	63.4	3.8
	April	0.1	3.3	27.1	1.8	210.4	50.1	2.1
	May	0.2	3.9	20.5	2.2	242.8	56.3	3.3
	June	0.1	3.3	15.6	2.1	238.7	48.8	3.0
	July	0.1	3.8	22.8	3.6	213.7	51.9	3.2
	Aug	0.2	1.7	10.5	2.5	206.5	153.1	2.6
	Sept	0.1	2.5	6.8	2.2	176.0	27.5	3.6
	Oct	0.1	2.1	8.7	1.6	182.1	29.0	2.7

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TABLE A-34. GROUNDWATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE LACKAWANNA DEMONSTRATION PROJECT DURING 1978

Well No.	Month	Fe	Mn	Al	K	Ca	Mg	Na
		mg/l						
Well 1	July	146.3	13.6	1.0	6.3	343.2	237.2	22.3
	Aug	106.4	12.7	0.5	6.2	287.1	137.2	22.6
	Sept	80.7	8.3	1.6	5.3	173.8	112.7	20.7
Well 2	July	34.1	2.3	<0.1	1.7	28.1	11.8	10.1
	Aug	27.2	2.1	0.2	1.8	25.7	10.9	9.7
	Sept	23.9	1.9	<0.1	2.4	32.8	11.8	9.7
	Oct	27.0	2.6	<0.1	1.9	27.3	15.8	10.0
	Nov	27.2	2.5	<0.1	1.8	24.8	11.9	10.0
	Dec	27.1	2.6	<0.1	1.8	27.3	12.6	10.8
Well 3	July	25.1	2.6	0.2	3.4	30.5	14.3	32.5
	Aug	21.7	2.9	0.6	3.9	32.8	15.0	37.1
	Sept	23.0	3.5	<0.1	4.3	44.5	20.6	41.7
	Nov	27.9	5.1	<0.1	4.8	57.4	27.8	42.7
	Dec	26.9	5.1	<0.1	4.9	54.9	27.1	43.3

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TABLE A-35. GROUNDWATER ANALYSES FOR SELECTED CHEMICAL CONSTITUENTS AT THE LACKAWANNA DEMONSTRATION PROJECT DURING 1979

Well No.	Month	Fe	Mn	Al	K	Ca	Mg	Na
		mg/l						
Well 2	March	30.1	1.8	<0.1	2.3	25.5	8.5	10.5
	April	31.2	1.6	0.7	2.2	24.3	8.9	8.8
	May	33.3	1.9	0.4	2.3	23.1	9.8	10.1
	June	25.0	1.8	0.1	2.2	23.4	10.0	8.5
	July	20.2	2.3	<0.1	2.7	25.8	9.4	7.5
	Aug	24.1	2.1	0.1	1.6	22.9	8.1	7.3
	Sept	23.4	2.4	0.1	1.8	32.5	11.1	7.5
	Oct	29.2	2.3	0.1	1.8	29.2	10.4	8.6

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